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The ILLUMINATING ENGINEER

ELECTRICITY · ACETYLENE · OIL · GAS

Edited by LEON GASTER

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Illuminating Engineering Society.
(Founded in London 1909.)

This number contains the account of the Discussion at the last meeting of The Illuminating Engineering Society, on March 16th, entitled: ***"The Rating and Marking of Lamps and the Best Methods of Specifying their Illuminating Value,"*** including a contribution on "The Practical Rating of Lamps" by Mr. F. W. Willcox.

ILLUMINATING ENGINEERING PUBLISHING COMPANY, Ltd.
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GAS LIGHTING.

EXHAUSTIVE scientific experiments have demonstrated the hygienic advantages of gas as a lighting medium. Investigations upon the bacterial content of an inhabited room lighted by gas reveal the cremation of organisms by the flames, and the value of the heat produced as an aid to ventilation. The air in a gas-lighted room is maintained in a hygienic condition, owing to the better ventilation and circulation of the air caused by the air currents set up by the moderate degree of heat evolved from the combustion of the gas.

The Gas Light and Coke Co.,
Horseferry Road, Westminster, S.W.

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EDITORIAL.

The Grading and Marking of Lamps.

The question of the grading and marking of lamps, discussed at the last meeting of the Illuminating Engineering Society on March 16th, is an exceedingly important one, both to manufacturers and to consumers, who look much more closely into the performances of lamps supplied to them than they formerly did. The importance of the matter was pointed out by the writer in an article in the *Times Engineering Supplement* as far back as October 25th, 1905. It is obviously desirable that some common procedure applicable to all illuminants should be followed, and the question is one that must be settled on broad lines. We have to strike a compromise between what the lighting engineer would like done, as ideal, and what the manufacturer can conveniently do.

In the first place a distinction—which is perhaps not generally appreciated—should be drawn between the "rating" or, more correctly, "grading" of lamps, and the "marking" of them. By the *grading* of lamps is meant the manner in which they are classified by the manufacturer in an ascending series by consumption or candlepower; by *marking* is meant what is actually marked on the lamp handed to the consumer. In considering this question the difficulties of the manufacturer have to be

very clearly recognised. Few people, for example, who are not directly brought in contact with the manufacture of incandescent lamps realise the large number of processes involved in the finished product. At each stage in the process there will inevitably be a certain number of "throw-outs," and therefore, in specifying the requirements of the final lamp, a reasonable degree of latitude must be allowed, or higher prices paid for specially selected lamps.

At present, largely no doubt on account of the greater precision with which consumption of gas and electricity can be measured, manufacturers prefer to grade their lamps on this basis rather than in candlepower.

To the consumer a series of lamps taking 10, 15, 20, 25, 30 watts is more useful than the old system of rating as 8, 16, 32 candlepower, the gaps in which are too big. It has sometimes been objected that on this system the consumer could not take the best advantage of improvements in efficiency ; for this improvement would merely lead to a series of lamps taking the same consumption as before but yielding more light. But a little consideration shows that if the intervals between successive lamps are small the consumer can readily reduce his consumption by adopting a smaller lamp in the series, at the same time maintaining the desired illumination.

On the whole, therefore, we consider that this system of grading lamps by consumption, which appears to have become general during recent years, is no hardship to consumers, provided the latter is afforded sufficient additional data as to the performance of the lamp in practice.

We now come to the second point—the marking of lamps. In the discussion before the Illuminating Engineering Society there was a general agreement that the consumer should be informed, both of the input in energy and the output in light. He wants to know the amount of gas or electricity that will be consumed, and what he will have to pay for it. But he should also have particulars as to the amount of light which he will obtain as a result. The requirements of the illuminating engineer are somewhat more precise than those of the general public. The former requires additional data such as the polar curve showing the distribution of light. In the majority of cases the lamps will be equipped with a reflector so that he must utilise, in his calculations, the polar curve of the finished unit. But in many instances it would also be an advantage to him to have the polar curve of the lamp alone, as this is useful in drawing conclusions as to its effect in combination with any particular reflector he has chosen or already possesses. Moreover, modern electric lamps possess such widely different distributions of light that a knowledge of their polar curves is really essential in order to draw any valid comparison between them. We think, therefore, that it would be well for the polar curves of typical lamps, as well as combination units with reflectors, to be given in the catalogue literature. We were glad to see the recognition of the need for such data, among both users and manufacturers, and that our suggestion that standrad types of lamps and lighting

appliances should be tested at the National Physical Laboratory met with approval. We would also suggest that when particulars of lamps and units are printed on boxes, labels, or wrappers accompanying them, the polar curve should be included. This practice is now being developed by one of the leading companies and could easily become general if demand is created for it.

It is essential that the illuminating engineer, in making use of such data, should feel confidence that the information afforded is comparable and strictly correct. For this reason we emphasise the valuable work the National Physical Laboratory could do in making these tests. Naturally the exact procedure for these tests would have to be carefully considered in order to guard against any possible misuse of the information supplied. But we think that these details could be satisfactorily arranged.

For the ordinary consumer the question of the information to be marked on the lamp itself is of importance. From a scientific standpoint much can be said for the view that either the total flux of light in lumens or the mean spherical candlepower should be indicated. This affords the most satisfactory comparison between different units, in terms of the total light available. Mr. Willcox has advocated strongly the adoption of the lumen-basis. In the United States, where lamp makers, supply companies and large consumers are in close co-operation, this method has found favour; as comparatively few people have to be consulted, such changes are more easily brought about there than here. In this country it would probably be difficult, as far as the general public is concerned, to depart from candlepower and substitute the lumen at present.

We are therefore inclined to suggest that for the sake of general comparison the mean spherical candlepower of sources should be given, and might be marked within a circle thus: (50) to indicate that the number refers to the mean spherical value. On the other hand, it has been suggested that for those of the public who do not readily understand polar curves the candlepower in the maximum direction should be indicated.

It should be understood that for manufacturing purposes considerable latitude would have to be allowed in the interpretation of these data. But even so it would be clear at least what the figures were intended to convey, and we should avoid the confusion of exaggerated claims based on candlepower in a special direction which have not infrequently proved troublesome, alike to manufacturers and the public. During recent years the electric incandescent lamp industry has become more fully organised, and these problems can now be considered with greater prospects of success than was formerly the case.

No doubt this discussion before the Illuminating Engineering Society will be helpful in enabling the standpoints of the various parties interested to be more fully appreciated, and will be borne in mind by the various committees interested in this matter.

Collective Advertising.

During the past month a series of articles by well-known authorities has appeared in the *Daily News* under the heading " Business Opportunities." Included in this series was a contribution from Mr. F. W. Goodenough describing the development and work of the British Commercial Gas Association. The activities of the Association represent one of the best examples of " collective advertising " in this country. The movement appears to have been suggested by the experience of the Gas Light and Coke Company, that their advertisements in various papers not only stimulated the demand for gas in their own London area but affected to a remarkable extent the business of provincial gas companies. At the present time the publicity work of the Association covers a wide area, and its influence is felt from John o' Groats to Land's End. Every gas company must confine its activities to its own area, but the collective advertising of the Association reacts in all directions so that all derive benefit. The movement, it is stated, has even been copied by the National Commercial Gas Association in the United States, where co-operative enterprise has long reached a high stage of development.

We have referred specially to the work of the British Commercial Gas Association as a noteworthy instance of what co-operative effort can accomplish. In this case the direct results of publicity were clearly visible. But we venture to think that the unseen and untraceable effect has been even greater. The lighting industry in this country is only now beginning to appreciate how much might be done by concerted effort.

We would like to see the electric lighting interests developing a publicity scheme similar to that prompted by the British Commercial Gas Association, thus encouraging healthy competition.

During the last few years lighting has come to occupy a distinctly higher place in the public estimation, but, this is nothing to what may come in course of time. Few people probably appreciate the strain of the patient educational work done by the movement for the industry during the past few years. It goes without saying that years of perseverance are needed before the initial inertia of people towards a new movement like this can be completely overcome. We can, however, already see results and we think that the present circumstances, inconvenient as they may be felt to be, are just those in which preparation should be made for the future. It is a mistake for the non-combatant section of the population to acquiesce in a passive attitude and " let things slide." It is their duty to make, if possible, greater efforts than usual to keep the mahcinery of industry intact, and to plan for the future so that those who have gone to the Front may find work waiting for them when they return. The British Commercial Gas Association, in deciding to continue their publicity with added vigour, have done the right thing. We count on the support of our friends to ensure that the illuminating engineering movement is likewise not allowed to suffer, and that the chain of continuous effort is maintained until brighter times arrive.

LEON GASTER.

TRANSACTIONS

OF

The Illuminating Engineering Society.

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The Illuminating Engineering Society is not, as a body, responsible for the opinions expressed by individual authors or speakers.

A METHOD FOR DETERMINING THE RANGE OF SEARCHLIGHTS.

By Prof. A. Blondel.

(*Continued from page* 90, *February*, 1915.)

Graphical Solution of Equations.

The simplest method of dealing with the above equations is to make use either of an Abacus with parallel scales or Cartesian co-ordinates.[1]

(1) *Abacus with Three Parallel Equidistant Scales.*

Assume $R=0$ and a known. On the central scale graduated in respect to I, we plot values of $\frac{1}{2}\log I$; on one of the other scales graduated in respect to the variable x we mark out values of the first term in the equation (6); on the third scale graduated in terms of the function of x_1 we mark out similarly values of the second expression in the equation. Once the three scales are prepared it is only necessary to draw a line joining corresponding points on the outer scales. Where this line cuts the central scale we can read off the value of $\log I$, and thus deduce I. Conversely if we assume a value for I we have to find values of x and x_1 such that $l=x-x_1$. If we know that $l=0$ (*i.e.*, that the observer is at the same distance from the mark as the projector) we omit terms containing $\log a$ in one of the parentheses in the second member of the equation, and we have only to consider a on one of the scales; also one can take the same x for both scales.

The introduction of the term $[R]$ is effected by a translation of the scale for I along itself, downwards.

One may also trace out another couple of outer scales when it is necessary to consider a as a variable.

A similar type of abacus can be used to solve equation (2) in terms of E', I and x.

Equation No. 6 may also be put into another very general form by putting $x_1=x-l$ and separating the second member in the equation into three terms in parentheses, thus—

$$\log I=\left(\frac{x}{gL}+H\right)+(2\log x+2x[\log a])+\left([R]-\frac{l}{gL}-l[\log a]\right)$$

$[\log a]$ being the modulus or absolute value of $\log a$.

[1] Following the "nomographic" methods of M. d'Ocagne.

If we suppose the final term to be *nil* the equation will indicate the value of $\frac{1}{2}$ log I measured on the central scale, which will be a mean between the values of the two first bracketed terms, measured out respectively as lengths on the two extreme scales; these scales being graduated in terms of x, while the central scale is graduated in terms of I.

Any introduction of a difference in the distance, l, will be equivalent to displacing the scale, I, along itself, the displacement upwards being equal to $\frac{l}{gL}+l[\log a]$. On the other hand the use of glasses, which is specified in the term R is introduced very simply by displacing the scale downwards through a distance equal to $[R]$.

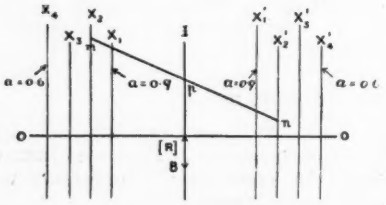

Fig. 1. **Abacus with three linear scales.** OO origin line of the three scales. I scale of candlepower expressed in megacandles; this scale carried values of $\frac{1}{2}$ log I. The scale can be so arranged that the zero falls above OO at a point B such that the absolute value of AB=$[R]$. The values carried by the scale x_1 are equal to 2 log x+x [log a], with a=0·9. Similarly x_2, x_3, x_4 correspond with other values of a, namely x_2 for a=0·8, x_3 for a=0·7, x_4 for a=0·6. $x'_1x'_2x'_3x'_4$ are vertical scales symmetrically placed with regard to $x_1x_2x_3x_4$ on the other side of the central scale I, and are graduated with reference to x_1. For the four values of a, the lengths carried by these scales represent the quantity

$$\frac{x'}{gL}+H+x'\ [\log a]$$

mn is a straight line by the two values x and x_1, traced respectively on the two scales x_2 and x'_2; both corresponding with a coefficient of transmission a=0·8. The intersection of mn on the scale I gives a point p and the corresponding value of I is read off on the scale at this point.

The two extreme scales, which are utilised for the functions of a are used in just the same manner for other values of a, the only condition being that they should be symmetrically placed with regard to and equidistant from the central scale dealing with a function of I.

Abacus in Cartesian co-ordinates.

The equations (7) and (8) can be readily adapted to Cartesian co-ordinates. It is sufficient to mark out the abscissa in terms of x and the ordinates in to be graduated in terms of log I, calculated from the equation after having suppressed the term R in the second member of the equation. One could also operate by suppressing the term x log a. We should thus obtain a curve :—

$$\text{Log } I=\frac{x}{gL}+H+2 \log x$$

applicable when log a=0, *i.e.*, when a=1. If $a<1$ it is necessary to replace the abscissa axis by an oblique axis OD inclined at an angular coefficient of 2 log a for equation (7) or log a for equation (8). Once the scales and the axes are determined, one can read off, with oblique co-ordinates values of I corresponding to values of x and *vice versa*.

The term $[R]$ involves a simple translation of the scale for I towards the base. Similarly, if x and x_1 are not equal, one may add a second member to equation (7) namely a term

$$-l\left([\log a]+\frac{1}{L}\right)$$

It will therefore be necessary to give the scale for I a shift upwards of

$$+\left([\log a]+\frac{1}{gL}\right)$$

This construction is quite practicable even if visual acuity does not follow the law of Fechner, for one can always trace the curve of log I experimentally as a function of l, as has been explained above.

The method discussed in the above analysis seems to solve, as completely as one can expect, the problem of determining the range of a projector in practice, Engineers and officers employing this

construction have only to determine the various empirical constants and can then construct by their aid the scales required to suit the local circumstances.

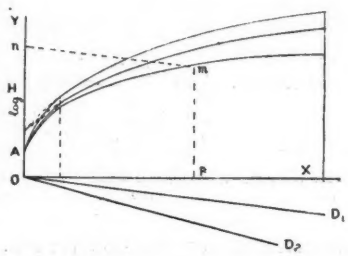

Fig. 2. **Cartesian Co-ordinates.** On the scale of ordinates OY the logarithms of I are marked out, and the scale is graduated in terms of I. The abscissa OX carries values of x and the scale is graduated in terms of x. ABC represents the relation

$$\log I = \frac{x}{gL} + H + 2 \log x.$$

In this case $a=1$. OD_1 is a straight line making making an angle β_1 with OX such that tang $\beta_1 = \log a_1$. Similarly the line OD_2 makes an angle β_2 such that tang $\beta_2 = a_2$. The ordinates compressed between OX and any line OD represent the term 2 x log a.

The curve $A_1B_1C_1$ is obtained by adding to the ordinates of ABC a supplementary term $=2x$ [log a], a being given any desired value a_1, for example $=0{\cdot}9$ $A_2B_2C_2$ is obtained similarly with a different value, a_2.

If one only wishes to make use of the curve ABC, with $a=1$, and to dispense with the construction of the others, it is enough, for all other values oi a to replace the horizontal axis OX by a corresponding oblique axis OD. For example the line mn has been traced parallel to OD_1. The ordinate On represents the candle-power necessary to enable an object situated at a distance x, corresponding with the abscissa Op, to be clearly seen (with $a=a_1$).

Another Form of the Range Equation.

Let us consider again the equation for the range of a projector established above :

$$\log I = \left(\frac{x_1}{gL} + H + x_1 [\log a]\right) + (2 \log x + x [\log a]) + R \ldots (6\ bis)$$

in which [log a] and [R] are moduli of the algebraic quantities log a and R, which are always negative. L and H are two associated constants, which can have two sets of different values, L_1 and H_1, or L_2 and H_2, according as the illuminated object is observed with an acuteness of vision above or below a certain critical figure.

In the first parenthesis of the second member of the equation one can, by assembling together the logarithms, write :—

$$\frac{x_1}{gL} + x_1 [\log a] = x_1 \log \left(\frac{a}{10^{\frac{1}{gL}}} \right) \ldots (6\ ter.)$$

10 being the base used for the logarithms.

The effect of the term $\frac{x_1}{gL}$, allowing for the acuteness of vision, is then the same as if the coefficient of transmission a, which intervenes in the path of the rays from the object to the observer, were replaced for this range x_1 by another fictitious coefficient of smaller value, $a' = \frac{a}{10^{\frac{1}{gL}}}$, or $a'' = \frac{a}{10^{\frac{1}{gL}}}$, as the case may be. The effect of acuteness of vision in the question of the range is thus analogous to the effect of atmospheric transmission.

But as soon as one introduces the coefficient a' defined as above, the constant $H = \log E_0$, specifying generally the minimum illumination necessary for the perception of form, becomes a constant of minimum illumination applying solely to the nature of the object observed —however small the acuteness of vision required may be.

From equation (6) we can derive the equivalent algebraic equation :—

$$I = \frac{E_0 x^2}{a^x (a')^x} \cdot \left(\frac{1}{k \frac{d^2}{p^2}} \right)$$

which can replace the expression given in the last number (p. 87) relating the candle-power of the source I and the apparent illumination E' or more precisely :—

$$I = \frac{E' x^2}{a^{x+x_1} \left(k \frac{d^2}{p^2} \right)} \quad \ldots\ldots (10)$$

The above considerations will serve to show the important part played by

acuteness of vision in the interpretation of observatione and results.

In practice the equation (6 *bis*), where $H=\log E_0$, is preferable.

The use of a fictitious coefficient of transmission a_1 no longer allows of the very convenient correction which I have indicated, as a means of allowing for the cases in which x is respectively equal and unequal to x_1, namely, a simple translation of the scale transposing a^{x+x_1} into

$$\frac{a^{2x}}{a^{x-x_1}};$$

whence $(x+x_1)\log a=2x\log a-l\log a$.

Units.

The units to be employed in researches on projectors are the *kilometer* for the unit of length, and the *lux* as the unit of illumination; the homogeneity of the formula involves the use of the "*megacandle*" (equal to one million candles) as the unit of candlepower. The *unit of acuteness of vision* employed by physiologists is that acuteness which enables printed letters, the breadth of which subtends five minutes and the thickness of the lines composing them one minute, to be clearly distinguished. The corresponding angle in radians is $\frac{1\cdot45}{1{,}000}$, equivalent to the angle subtended by a height of 1·45 metres at a distance of 1 kilometre. The constant $L=Bb$ is the product of greatest length in metres of object observed, b, and the constant B.

We can thus deduce the value of the acuity as a function of normal acuteness of vision for an object of height b, seen a distance of one kilometre, namely $\frac{1\cdot45}{b}$, b being measured in metres: this constant will be unity when the acuteness of vision is normal at an illumination of 1 lux.

Order of Magnitude of B.

According to Koenig's researches it would be about 0·43 for cone-vision and approximately only 0·043 for rod-vision. Hence in our formula we shall have $B=\frac{0\cdot43}{1\cdot45}=\frac{1}{3}$ $\left(\text{whence } \frac{1}{Bb}=\frac{3}{b}\right)$, when the acuteness of vision is in the upper limit (above 0·15) and the cones are in use. If, for example, an object gives rise to an acuity $V=0\cdot20$ at 1 kilometer, $\frac{1}{Bb}=\frac{3\times0\cdot20}{1\cdot45}=0\cdot41$.

For acuteness of vision of the lower order (below 0·15) we should have $B=\frac{1}{30}$ about, whence $\frac{1}{Bb}=\frac{30}{b}$.

Signification of the Constant L.

The meaning of the constant H has been explained above, but it is important to consider that of the constant L, which has the dimensions of length. When one observes with the naked eye, and in a perfectly clear atmosphere, the equation (4) of p. 89 may be written:—

$$\frac{x_1}{L}=\log\frac{E}{E_0} \quad \ldots\ldots (4\ bis)$$

We have, therefore, $x_1=L$ when $\frac{E}{E_0}$ is equal to the base of the logarithms employed, in the case 10. L is thus the distance at which one can see an object having a visibility just sufficient for the perception of form, when it is submitted to an illumination equal to ten times the ordinary illumination E_0. This definition of the constant L has the advantage of eliminating the length characteristic of the object, b, which may often prove difficult to define. The formula for range then assumes quite a general character, granted that the constant L can be determined by direct observation.

Determination of Constants.

E_0 and L can be obtained by tracing the line of points relating x_1 and L according to equation (11), $x_1=L\log(E-H)$, x_1 being the ordinates and $\log E$ abscissæ. L is then the inclination of the line and H the intercept from the origin on the abscissa. This will be always positive for cone-vision, but may be negative in the case of rod-vision.

I have already suggested the methods of making this determination (p. 89).

Practical limits of the values B and H.

The point of transition between the two cases corresponds to a value for the normal acuteness of vision about 0·15, and it is interesting to examine some practical examples in order to determine whether or no this value will be exceeded.

It may be recalled that normal acuteness of vision implies the power to distinguish those objects whose greatest length is not less than 1·45 metres at a distance of one kilometre.[1] In practice a troop of infantrymen having an average height of 1·75 metres should be visible at a distance of at least 500 metres.

This is equivalent to an acuteness of vision of $\frac{1{\cdot}45}{1{\cdot}75}\times\frac{500}{1000}=0{\cdot}41$ of the normal

At 250 metres the acuteness of vision called for would be reduced to 0·20. In practice vision is achieved almost exclusively by the cone-area of the retina. If artillerists observe the above troop of infantry by the aid of glasses, having an average magnification of 8, the distance of observation might be10 times as great.

Again, take a farmhouse 6 metres high is observed by artillery (without using glasses) at a distance of 10 kilometres, the acuteness necessary is

$\frac{8}{10}\times\frac{1{\cdot}45}{6{\cdot}00}=0{\cdot}20$ about.

It is thus evident that in the use of projectors on land the constants B and H to be determined involve cone-vision.

The same would apply to observations at sea when one is examining objects of the order of magnitude 6 m. × 1 m. 20 on ships, with a telescope having a magnification of 10, and at a distance of 10 kilometres.

Only the scouting work of the navy (torpedo boats, submarines, &c.) would call for rod-vision, when the necessary acuity falls under 0·15.

Another case in which one meets with rod-vision is furnished by work with the headlights of automobiles and locomotives. Here the range of observation does not exceed 500 metres, and the objects to be recognised are usually men, vehicles, &c., the height of which always exceeds the normal value of 1·45 metres.

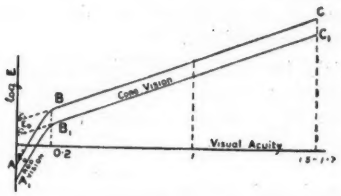

Fig. 3. **Acuteness of Vision Curves** (Double Law of Fechner) as a function of the illumination (after Koenig). ABC, $A_1B_1C_1$ are two curves corresponding with two distinct types of objects. AB and A_1B_1, approximately linear and parallel, correspond with rod-vision. (By red light the inclination of these lines would be less.) BC, B_1C_1, also approximately linear and parallel, correspond with cone vision. (By blue light the inclination of these lines would be steeper.)

C, C_1 are the maximum limits of acuteness of vision, which vary according to the observer (being, according to Koenig, 1·5—1·7).

E_0, E_0' represent the minimum illumination according to Fechner's Law corresponding with the ordinate intercepts of BC and AB respectively; θ, θ' the corresponding inclinations with the ordinate axis.

Tang. θ=B, a constant. $\log E_0$=H, a constant
Tang. θ'=B, a constant $\log E'^{\theta}$=H', a constant

Note that $\log E'_0$ is here generally negative since E'_0 is less than 1 lux and $\log 1=0$.

Determination of constants p and k.

The diameter of optical aperture, p, can be measured by a micrometer having a scale in the eyepiece of the telescope. The constant k can be rapidly measured by alternately observing, with one eye, a white screen as seen through the telescope and through a photometer with adjustable absorbing prisms which can be regulated so as to get equality of brightness.

IMPORTANCE OF PART PLAYED BY ACUTENESS OF VISION.

It has been explained above that the coefficient used to allow for acuteness of vision has the value $a'=a.10^{-\frac{1}{eB\theta}}$; if we take the data given by Koenig we

[1] The maximum acuteness for some persons may, according to Koenig, reach 1·5—1·7 of the normal.

find for an object giving an acuity 0·20 at 1 kilometre, $a'=\frac{a}{10^{0.4}}$ or $a''=\frac{a}{10^{4.1}}$ according as we are dealing with cone- or rod-vision. This figure is evidently of supreme importance in determining acuteness of vision.

Take for example an object 7 m. 25 in length (*e.g.*, house or boat) seen at a distance of 1 kilometre ($x=x_1$) with an acuteness of vision $V=\frac{1·45}{7·25}=0·20$ of the normal, and by the aid of a searchlight whose intensity just suffices for visibility. In order that the same object may be seen with equal clearness (again with the naked eye) at a distance ($x=x_1$) five times as great, it will be necessary (assuming a value for a' corresponding with cone-vision) to obtain an apparent illumination 100 times as great; that is to say we require 100 times the candle-power of the source; at the same time the increased distance will involve a multiplying factor of $5^2=25$ and the atmosphere absorption will require yet another increase of $\frac{a^{10}}{a^2}=a^8$. For example, if $a=0·70$ $a^8=0·06$.

Thus the total candle-power required will have to be :—$\frac{100\times25}{0·06}=42{,}000$ times as great as before.

This example shows that the visibility of the object decreases very rapidly, and much more quickly than the range of a searchlight, in which the factor $\frac{a^x}{x^2}$ occurs, or than the range accorded to Nerz's formula $\frac{a^{2x}}{x^4}$.

Application to Headlights of Locomotives.

One of the objects of the headlights on a locomotive is to enable the engine driver to perceive an obstacle, such as a man crossing the line, in time to pull up.

Some important tests have been recently carried out on this subject by several railway companies in the United States, notably by the American Railroad Master Engineers' Association[1] and the results have been expressed in the simple parabolic formula : $I=Ax^n$. Here, A and n are constants whose value depends on the nature of the light employed, and the colour of the clothes of a man of average height assumed crossing the line in the path of the rays from the headlight; n varies from 2 m. 60 to 4*m*.

It is evident from the preceding considerations that formulæ of this character cannot represent the conditions exactly, and should be replaced by a formula of the type (10) :—$I=\frac{Ax^2}{(a'')^x}$, or of the type (6 *bis*), the constants being deduced on the assumption that we have to deal with rod-vision.

Analogous formulæ could be established for the observation of objects on the road in front of an automobile and in this case the constant H would have much smaller values owing to the ready manner in which objects can be distinguished against the illuminated road as a background.

Influence of the Nature of the Light and the Colour of Observed Objects.

Visibility depends very much on colour. For example, in the experience of the American Commission, quoted above, it was found that a man dressed in light grey or even in blue can be seen at a distance very much greater than a man dressed in black; for example with a candle-power of 8,000 the relative figures for the range are respectively 350, 180 and 125 metres. This result shows that

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[1] Special Report, Headlight Committee (A.R.M.M.A., June, 1914). See also J. L. Minick, on Locomotive Headlights (Trans. Illuminating Engineering Society, 1914, No. 9, pages 909-925).

According to these results the range of a headlight is actually insufficient to enable the driver to pull up in time to escape an observed obstacle; especially if one takes account of the inevitable loss of time in the period of physiological reflex between the instant that the object is observed, and the moment when the brake is applied. This period may be also increased by *visual inertia*, of the type studied by A. Broca and Sulzer (Journ. de Physiologie and Pathology, No. 4, July, 1903).

at night illuminated objects detach themselves appreciably from a black background, whereas during the day the neighbouring area is always more or less brightly illuminated. If one applies these considerations to the uniforms of infantrymen, one recognises that the grey-blue uniforms which give a minimum of visibility by day are, on the other hand, less favourable in this respect by night than a dark blue. The disadvantage of light blue is especially marked in the case of objects illuminated by the electric arc, the rays from which are richer in the blue and violet than other artificial illuminants.

On the other hand a monochromatic source of light would give rise to an acuity greatly superior to that attained from mixtures of various colours, such as exist in ordinary polychromatic sources—on account of the effect of chromatic aberration in the eye.[1] From this standpoint projectors having gilded mirrors, which retain the most valuable rays but suppress those considerably in the highly refracted region of the spectrum, are favourable to visibility. In order to accentuate the contrast-effect it is desirable that the direction of view of the observer should be inclined at as great as possible an angle to that of the beam of the searchlight.

This condition is also desirable with a view to diminishing lateral illumination of the retina which has an unfavourable effect on vision. Moreover the use of the less refrangible rays is also beneficial in reducing the quantity of light scattered by the minute drops of water or particles of dust in the air, forming a luminous haze and interfering with clear vision; this is proportional to the fourth power of the wave-length.

[1] Cf. M. Luckiesh, *Electrical World*, 19th August, and 1911, p. 450, 18th November, 1911, p. 1252. J. S. Dow, *Electrical World*, 14th October, 1911, p. 955. Louis Bell, *Electrical World*, 9th September, 1911, p. 637.

SEARCHLIGHTS;

Some remarks on the more usual electrical systems of operation.

By J. F. Crowley.

I was much interested in the discussion that took place before the Society on "Searchlights," and can support Mrs. Ayrton's remarks regarding the importance of the electrical apparatus in the production of a steady light for searchlight work.

For searchlight arcs, direct current is almost invariably used, being both more efficient and satisfactory for this purpose than alternating current.

The following are the direct current systems more generally employed:—

(a) The feeding of one or more lamps from ordinary supply mains, a stability resistance being used for each arc.

(b) A separate generator for each arc, with or without a stability resistance.

(c) A separate converter for each arc, used with or without a stability resistance, connected to the mains of the supply system, and designed either for:—

(1) Complete transformation, or
(2) Partial transformation.

For work where heavy currents are dealt with, system (a) is very uneconomical, while, in addition, the shape of the electrical characteristic is a straight line, the inclination of which depends upon the voltage of the supply. Where a steep characteristic is required, therefore, the supply voltage must be high, and the energy wasted in the system will be considerable.

The arrangement in case (b) is more particularly used for isolated searchlights, and for those which are required to be portable, but not frequently on board ship where many searchlights are as a rule installed.

Case (c) is the more general one for searchlights for ship use, as the ring main system is usually of high voltage and requires to be reduced for use on the lamp.

Some years ago I carried out a number of experiments with a view to designing a searchlight generator of the converter type, that would give the best results. Generally speaking, such generators and converters should possess :—

(a) Extreme lightness and portability, which necessitates the utilisation of steel parts and of aluminium where this metal can be employed.

(b) Compactness, particularly where the apparatus is to be used on ship board, in which case it is usual to employ vertical spindle machines, which generally permit of the best utilisation of the space available.

(c) An electrical characteristic which will give the best results on the lamp.

Points (a) and (b) are purely matters of design, and do not affect the light obtained from the lamp ; (c) is, however, of the utmost importance if a stable arc is to be maintained.

The shunt feed series strike lamp is one in common use, and to enable what follows to be understood, it may be well to briefly describe its action. On closing the lamp circuit, the carbons may either be in contact, or, as is sometimes the case, apart.

If they are in contact, a heavy short circuit current will pass through them, and, therefore, through the series striking coils, on which the carbons will be immediately pulled apart, and the arc "struck." Should the carbons be already apart, however, the full open circuit voltage of the generating system will be thrown across the terminals of the shunt feed coil, which will cause the carbons to gradually feed until they come into contact, on which a current will flow of sufficient value to operate the series coils and thus cause the arc to "strike."

Once the arc is "struck," the duty of the series coils is ended, and the shunt coil has to maintain the arc by feeding forward the carbons as they burn away. This it does in the following manner. As the carbons burn, the resistance of the arc increases, the lamp current falls, and the supply system is so arranged that on the current falling below the value for which the apparatus is adjusted, the voltage rises sufficiently to operate the shunt coil and bring the carbons to the correct distance once more. On the other hand, when the current reaches a high value, as, for instance, when the carbons come together, the voltage falls, and the shunt coil ceases to feed. It is on the capability of the system to give on a slight fall in current a rapid and sufficient rise in voltage to overcome any changes in the arc due to irregular burning and to fulfil the conditions of feed just outlined, that the whole question of stable burning of the arc depends, so far, at any rate, as this is affected by electrical considerations. Some misunderstanding would seem to exist on this point, since stress was laid in the recent discussion on the necessity for having :—

(a) A high voltage of supply, and

(b) A large resistance in series with the arc.

What should actually be specified is that the load characteristic of the generating apparatus should be such as to give a steep curve over the working range of the lamp, *without* a stability resistance, which is inefficient, and *without* requiring a high open circuit voltage, which, among other disadvantages, may produce sparking at the shunt feed contacts. A high current value is desirable on short circuit when the carbons come together.

Without entering into detail, it may be said that these are the essential requirements of the electrical system for searchlight work. When a generator or converter gives a satisfactory characteristic, no stability resistance of any kind should be required, provided the resistance of the leads is, as is usually the case, of such a value as to prevent trouble arising from short-circuit effects. Careful adjustment of the striking and feeding devices of the lamp when operating with the generator is necessary if the best results are to be obtained. The whole system is very sensitive, and slight want of adjustment may produce unstable burning.

For lamps of the usual type with horizontal carbons, a magnet which has for a magnetising coil the single turn consisting of the carbons and supports, through which the lamp current flows, is used to maintain the central burning of the arc, which has otherwise a tendency to burn upwards, due to the air draught produced by the flow of the heated air in the lamp through the openings at the top of the enclosing case.

THE RATING AND MARKING OF LAMPS AND THE BEST METHODS OF SPECIFYING THEIR ILLUMINATING VALUE.

Proceedings at a meeting of the Society held at the House of the Royal Society of Arts, 18, John Street, Adelphi, London, W., at 8 p.m., on Tuesday, March 16th, 1915.

A MEETING of the Society was held as stated above, Mr. Leon Gaster being in the chair.

The minutes of the last meeting having been taken as read, the Hon. Assistant Secretary read out the names of the applicants for membership in the usual way.

The CHAIRMAN then called upon Mr. F. W. WILLCOX to read his contribution (see p. 163), and subsequently Mr. C. H. WORDINGHAM opened the discussion in which the following also took part :—

Mr. C. C. PATERSON, Prof. J. T. MORRIS, Mr. J. MACINTYRE, Mr. J. T. FLETCHER, Mr. T. E. RITCHIE, Mr. J. G. CLARK, Mr. M. FOULDS, Mr. LE MARECHAL, Mr. J. S. DOW, Mr. F. S. TILLEY, Mr. STROUD and Mr. BUSSEL.

Written contributions to the discussion by Professor SILVANUS P. THOMPSON, Mr. F. W. GOODENOUGH, Mr. E. ALLEN, Mr. HAYDN T. HARRISON, Mr. W. J. A. BUTTERFIELD, and Mr. GEO. KEITH were also read by the ASST. HON. SECRETARY.

The CHAIRMAN called for a vote of thanks to Mr. WILLCOX for his paper, and to Mr. WORDINGHAM for coming to open the discussion. Finally it was announced that the **next meeting** would take place on **April 27th,** when a discussion on "**Visibility; its practical aspects**" would be initiated by Mr. C. C. PATERSON and Mr. B. P. DUDDING.

NEW MEMBERS.

At the meeting of the Society on March 16th the names of the following applicants for membership were read out :—

Cheetham, A. S.	Engineer, Sir W. Armstrong, Whitworth & Co., Ltd., Elswick Works, NEWCASTLE-ON-TYNE (2).
Evered, G. J.	Managing Director of Messrs. Evered & Co., Ltd., Surrey Works, SMETHWICK (2).
Gilbert, Walter	The Bromsgrove Guild, BROMSGROVE, Worcestershire (2).
Johnson, J. H. *M.I.E.E.*	Electrical Engineer, Messrs. Crompton & Co., CHELMSFORD (2).
Staniforth, H.	Gas Engineer, 88, North Side, Clapham Common, LONDON, S.W. (2).
Tilley, F. S.	Managing Director, The Tilley High Pressure Gas Syndicate, 53, Kingsland Road, N.E. (2).

In addition the names of members announced at the previous meeting on February 16th* were read out again and these gentlemen were formally declared members of the Society.

* *Illum. Eng.*, Lond., March, 1914, p. 101.

THE RATING AND MARKING OF LAMPS AND THE BEST METHODS OF SPECIFYING THEIR ILLUMINATING VALUE.

In view of the great variety of lamps and reflectors now available, and the wide difference in the distribution of light yielded by them, the question of the methods to be adopted for the rating and marking of lamps, mantles and lighting units has become a very important one.

Previous to the discussion on this subject at the last meeting of the Society on March 16th, the following list of points was prepared for consideration :—

(1) The rating of electric incandescent lamps in watts *versus* candle-power.

(2) The discussion of the following resolution passed at a recent meeting of the Committee on Nomenclature and Standards of the Illuminating Engineering Society in the United States :—

(A) That the output of all illuminants should be expressed in lumens.*

(B) That illuminants should be rated upon a lumen basis instead of a candle-power basis.

(C) That the specific output of electric lamps should be stated in lumens per watt, and the specific output of illuminants dependent upon combustion in lumens per British thermal unit per hour.

(3) What additional particulars are necessary to be furnished to illuminating engineers for use in planning lighting installations ? (viz., polar curves of light distribution of the bare lamp, or of the unit composed of lamp and reflector, &c.). Should the candle-power of lamps and lighting units be stated in terms of mean spherical candle-power, mean lower hemispherical candle-power or candle-power in a particular direction ; or the ratio between maximum and mean spherical candle-power of the lamp given ?

(4) The desirability of adopting, in all literature on illumination recognised symbols for the candle-power as follows :—

I_s=mean spherical candle-power.
I_u=mean upper hemispherical candle-power.
I_l=mean lower hemispherical candle-power.
I_α=candle-power at an angle α with the vertical.

(5) The practicability, in specifying interior lighting, of requiring a certain illumination on the working plane in foot-candles, as compared with furnishing a certain wattage, consumption of gas. or candle-power per square foot of floor area.

* *A Lumen* may be defined as the flux of light required to produce an illumination of one foot-candle on an area of one square foot.

THE PRACTICAL RATING OF ELECTRIC INCANDESCENT LAMPS.

By Francis W. Willcox.

Contribution to a discussion at the meeting of the Society held at the House of the Royal Society of Arts (18, John Street, Adelphi, London, W.), at 8 p.m., on Tuesday, March 16th, 1915.

At the meeting of this Society on May 21st, 1914, Mr. A. P. Trotter, in his paper on "The Nomenclature and Definition of Photometric Units," put forward a very able plea in support of the candle-power as the fundamental unit.

In the discussion on this paper, Mr. C. C. Paterson defended the case for the luminous flux and showed the deficiencies of the simple candle-power as a unit for use in general lighting problems.

I am not concerned here with the theoretical aspects of this subject, because these have already been fully and ably covered at the meeting referred to. I only refer to this discussion in order to point out the very clear evidence it presents that candle-power as an all-round lighting unit has been found wanting. It is being displaced as a practical rating unit, largely as a result of its own deficiencies.

The primal reason for this is found in the fact that candle-power is a somewhat loose term, readily abused, and is being used in a dual sense. As Mr. Paterson pointed out in the above discussion, candle-power is used as a conception of luminous intensity or power and also to express the numerical value of a source of light. Furthermore, candle-power being a derived unit and not a fundamental one, its insufficiency became evident when an attempt was made to establish a complete system of lighting units and co-ordinate these with the actual expenditure of power required to produce the light.

The writer well remembers the time in the United States, in the early days of the metal filament lamp, when the rating of electric incandescent lamps was changed to total watts as a practical size rating in place of candle-power (which had previously been used with carbon filament lamps). This change did not arise out of any theoretical considerations, but purely out of a practical one, viz., the desire to obviate the misleading values it was possible to assign to electric lamps under a rating by candle-power. Serious abuses had arisen in the cases of special lamps, such as the "Nernst" lamps, which, by virtue of their special construction (the frame of the lamp acting as a reflector), were able to give a multiplied value of apparent candle-power beneath the lamps. These lamps were accordingly rated on the candle-power value of this downward maximum beam of light.

The glow lamp manufacturers were compelled to meet such fictitious ratings by adopting similar tactics—silvering the top portion of their lamp bulbs and employing a special horizontally displayed filament to obtain downward light concentration and a maximum apparent candle-power value. This led to considerable confusion and uncertainty in ratings and values. To overcome these abuses, the electric glow lamp industry fell back on the wattage of the lamp and began rating lamps in total watts. This provided a simple, definite rating that could not be manipulated as candle-power had been.

In this matter the incandescent lamp simply repeated the history of the arc lamp which, on the candle-power basis, had been rated at very high values (the value of the maximum ray), resulting in the dropping of candle-power as a unit of rating for the arc lamp and the adoption of watts or amperes instead.

The rating of incandescent lamps in total watts, therefore, in place of candle-

power, forced itself into practical use purely as a defence against abuses which had grown up with the unit of candle-power. This change met with a great deal of opposition at the time, as engineers and users of electric light had become accustomed to the term "candle-power" and believed, or thought they believed, that no other term could take its place. Nevertheless, the practical reasons which prompted the adoption of the total wattage rating prevailed over all opposition and forced its acceptance into general practice. Curiously enough, this change which took place in the States appears also to have been independently adopted in Great Britain, and has been employed without any serious objection or any practical difficulty for the past four or five years.

It has been found that it is just as easy to form an idea of the light a lamp gives when it is called a 40-watt lamp as it was when it was called a 32-c.p. lamp. A lamp by any other unit will shine as brightly. In fact, as far as the public is concerned, a simple indicating number without any terms will suffice, after an experience, to determine what is required. Most people don't know and don't care what 32 c.p. really is—they get an idea of the effect by trial and use, and that is all they want.

The subsequent developments in incandescent electric lamps, the multiplication of shapes of filament and the considerable advances in efficiency realised in the past year or two, have all accentuated the value of the total watts rating as a practical size rating and thus confirmed it more fully than ever.

Now I would like to point out that there has been no complete abandonment of the candle-power unit. To express the total luminous power or flux of light given by a lamp, we employ such values in one form or another as the necessary means of expressing the efficiency of a lamp. This efficiency is given, of course, by the ratio of the luminous output to the energy input or total watts consumed by the lamp. As a practical size rating, however, for the incandescent electric lamp, the total watts has been adopted by force of the conditions mentioned above and for the reasons detailed hereafter. The watts remain fixed and the candle-power values change. The result of this is to give increased values of candle-power with every advance in efficiency.

Now this is the desirable plan (as compared to the alternative, *i.e.*, a fixed candle-power with changing total watts), as we shall see when we review the summarised reasons for the watt rating. The general trend in practice is to higher lighting values, *i.e.*, to an advance in candle-power which the rating on a fixed watt basis insures.

The adoption of the watt rating has resulted in the establishment of a line of fixed standard watt values, 10, 15, 20, 30, 40, 60, 80, 100, 200, &c., watts for metal filament glow lamps, which all manufacturers have adopted. While candle-power values will still be used as needed, they will be derived values obtained by dividing the watt rating by the efficiency.

It can readily be understood, for example, that it is very important to the largest class of lamp-users—electric supply station customers—to have the total watts of the lamps stated and fixed, as light is purchased on the basis of the watts consumed. With advances in efficiency, however, this would not be possible if we had to provide a fixed line of candle-power sizes, as with every advance in efficiency the total watts would have to change and there would be continual shifting of the watt consumptions of the various lamp sizes, which would complicate the situation for supply stations and their customers. In the old carbon days, when lamps were rated in candle-power, the efficiencies of lamps were practically stationary and this complication did not arise.

With the rating in total watts, it is not intended to deny any user the privilege of having the candle-power (or other luminous unit value) of the lamp where it is necessary to have it; but such candle-power values will not be fixed values, as this would prevent the very desirable condition of a fixed total wattage which is found to be such an eminently practical basis for central station consumers.

With this general introductory explanation, we can now briefly review the summarised reasons for the adoption of total watts as the basis for the rating of metal filament lamps.

TABLE I.

STANDARD SIZES OF TUNGSTEN INCANDESCENT LAMPS. FIXED TOTAL WATT RATING AND DIVIDED CANDLE-POWER VALUES CORRESPONDING.

Voltage.	Size in Fixed Total Watts Rating.	Candle-Power as derived at present Efficiencies.	Candle-power as it would be with about a 10% advance in Efficiencies.
100 to 130	10	8	8
	15	12	12
	20	16	16·7
	30	25	26
	40	33	35
	60	50	54·5
	80	67	73
	100	90	100
	150	150	150
	200	200	200
	400	400	400
200 to 260	15	10	10
	20	14	15
	30	22	23
	40	30	33
	60	48	52
	80	64	70
	100	80	91
	150	120	136
	200	160	182
	400	320	400

TABLE II.

LAMPS WITH FIXED C.P. SIZES SHOWING THE CHANGE REQUIRED IN TOTAL WATTS WHEN EFFICIENCIES ARE ADVANCED.

Sample line of sizes in Fixed Candle-Powers.	Derived Total Watts Resulting at present Efficiencies.	Derived Total Watts on scale of about 20% advance in Efficiencies.
15	20	16
20	25	20
25	30	25
30	40	30
40	50	40
50	60	50
60	75	60

The last column above, it will be seen, simply repeats the total watt values in the second column. The same total watt values are shown advanced one step in the candle-power line. (See par. No. 8 of summarised advantages of total watt rating, p. 166.)

Practical Reasons for adopting Total Watts as a size rating for Electric Glow Lamps.

"(1) Total watts is a more positive rating, as watts are definite, unvarying and a physical quantity, whilst candle-power is more or less indefinite and is physiological quantity. We have the difference between the Hefner candle-power standard and the English standard, between the mean spherical, the mean hemi-spherical and the mean horizontal, &c., as well as the candle-power given with different forms of reflectors. We have no such differences with watts. A watt is a watt whether the candle-power is measured as spherical, horizontal, or otherwise, or whether measured in Germany or in England.

"(2) The correct determination of the candle-power of a lamp requires some equipment and trouble in any case. It is hardly a practical matter for the generality of users, including many engineers, to determine the candle-power of lamps, and the history of the lamp business proves this conclusively. We can go back to the old carbon lamp. Anybody in the lamp business knew how easy it was to fool the public in respect of candle-power. Lamps might be called 16 candle-power lamps when they were only 12 or 13, and then be passed off as having an efficiency of 4 watts per candle when they were actually 5. The difference between 4 and 5 watts per candle in efficiency makes a great difference in life and candle-power performance, all as a result of an underrating of two or three candle-power which the eye does not detect, and which customers do not measure because they have not the equipment and experience.

"(3) The wattage of lamps is very easily and definitely obtained by a simple wattmeter reading. Lamp values therefore can be more easily checked in watts.

"(4) With total watts as the rating we have a more even fixed value for the period of the lamp's burning life. The total watts of the lamp change very little, not over 5 per cent., in the same period in which the candle-power declines some 20 per cent. In the matter of time element therefore the total watt rating is a more definite and unvarying rating than the candle-power. The candle-power rating to be exact must be described as the 'initial' candle-power, or the value at start of a lamp's life; or the 'average' candle-power, or the average value during the period of the lamp's life; or 'final candle-power,' or value at the end of the lamp's life.

"(5) As light is sold on the wattage basis, the total watts consumed by the lamp is the most important thing to know. The majority of the lamps are employed on the circuits of the central supply stations where a definite value in watts is required for both the station engineer and the consumer for estimating or checking the cost of the service. In all other cases, such as private plants or Government installations, the total watts value is also an important matter for apportioning the costs, the losses in lines, and the capacity of supply apparatus.

"(6) Practical lighting work and illumination determinations are to-day almost universally calculated upon total watts as a basis. This is the standard practice of most of the engineers and companies doing this work in England and America. The total watts form a much more convenient and practical unit for estimating lighting work, and simplify the determination generally. If we wanted to determine the values for lighting a room, we should take the square feet of the room, and multiply it by a constan) qtaken from the illumination value table and representing the watts per sq. ft. required to give the desired illumination), the result being a certain total watts indicating the lamps required. In this way we determine the actual requirements without reference to candle-power.

"(7) The adoption of total watts as a primary rating for lamps is the natural outcome of practical experience. It repeats the same evolution that took place in arc lamps, for which the candle-power rating was abandoned years ago in favour of watts. Manufacturers were rating their arc lamps in thousands of candle-power, whilst the actual candle-power of a lamp on the mean spherical basis was very much less. The practice was to take the value of the maximum ray, and it was finally decided to drop candle-power rating because of such abuse and overrating.

"(8) With candle-power as the fixed primary rating the total watts will have to be varied from time to time as improvements in efficiency come along, and these changes would cause confusion and introduce complexity in the business of lamp manufacturers and also for the consumer and supply engineer. This would have been particularly the case in the last two years when the efficiencies of incandescent Tungsten lamps have advanced from 1·25 to 1·0 watts per candle. If we had started two years ago with the scale of wattages we have to-day, and instead of carrying a fixed wattage had held to a fixed candle-power, and lowered the wattage as we went up in efficiency, we should have gone down so that we would practically have the same watt scale over again on the lower basis—lamps would simply have been shifted 20 per cent. in candle-power. (See Table II.) In the meantime we should have had confusion, and we might as well have held to the fixed watt values in the first place and increased the candle-power, instead of going through the scale of evolution for two or three years and finally arriving at the same watt values in the end. We have more recently had the introduction of half-watt lamps with previous efficiencies doubled. These lamps, and the improvements in lamp efficiencies to come, constitute still greater changes than we have had in the past. These changes will emphasise this point even more in the future than they have in the past.

"(9) The total watts is the unit generally employed for electrical work and the one most widely dealt with and known to the industry. We have watts as a basis, for example, in practically all electrical apparatus, transformers, meters, motors—(HP., which is of the same character as watts)—and heating apparatus. The energy these devices consume is the basis of the practical rating.

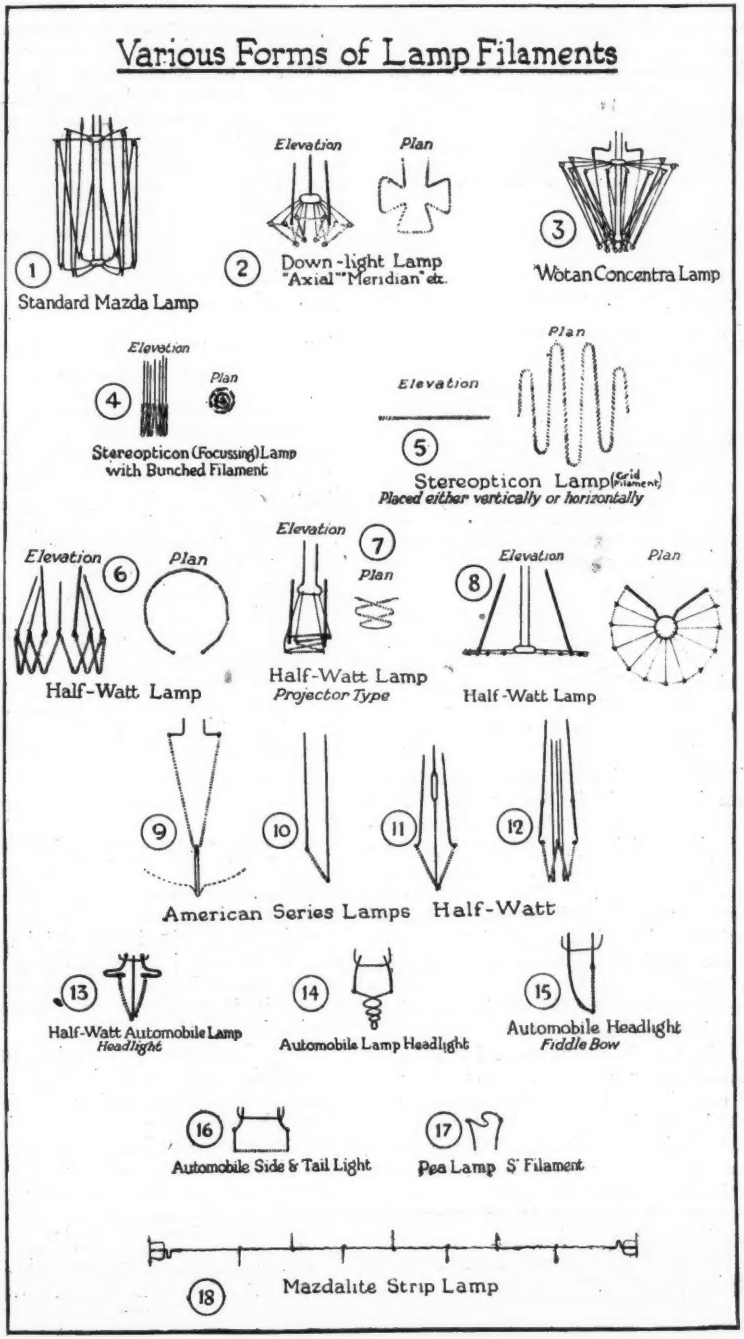


FIG. 1.—Various forms of Lamp Filaments.
(All forms, except 1 and 14, are made with helix-wound wire.)

"(10) The primary rating in watts simplifies matters. It is practicable to get along with total watts for lamp rating without candle-power, but if candle-power be employed as a primary rating you must also use total watts.

"(11) With fixed candle-power rating it is necessary, by reason of the lower efficiency of 200—250 volt lamps, to have two sets of watts values, one set for 100—130 volts, and another, a higher set, for 200 volts. This would undoubtedly call attention to the lower efficiency of 200 volt as compared with 100 volt systems. I think you would have serious complaints from central station engineers of the 200 volt systems if they had to employ a 25 or 35 watt lamp whilst a neighbouring station supplying 100 volts were able to offer a 20 or 30 watt lamp.

"(12) The fact that watts have been used as a primary rating by 80 per cent. of the manufacturers in England, ever since the Tungsten lamp was introduced, some four or five years ago, proves that the use of total watts rating is not a new untried thing; it is the standard practice in the United States, and in Canada as well as in Great Britain."

These, then, are the reasons for the watt rating of electric glow lamps which have prevailed, and which are, it will be noted, nearly all purely practical reasons derived from experience.

It has always seemed to the writer that the power consumed by the illuminant is a very natural unit to have and to work upon, as it only needs to be coupled with the efficiency value to give immediately the actual luminous output. As engineers we are all concerned chiefly with the question of power expenditure, and, in fact, it is hardly possible to consider the central element of engineering, *i.e.*, efficiency, without first considering power or energy. As the *Lighting Journal*, U.S.A., states in a recent editorial:—"There is no excuse for the engineer whose business it is to handle power balking at the thought of light as power. The Committee on Nomenclature and Standards of the American Illuminating Engineering Society defines the light or luminous flux of a lamp as 'radiant power evaluated according to its capacity to produce the sensation of light.' Radiant power is expressed in watts which should be sufficiently comprehensible by the engineer, and the evaluating factor (efficiency) is a simple number. Consequently light flux can be described and, what is more, measured as watts, given the proper evaluating or efficiency factors."

It is not necessary to measure the candle-power of lamps to determine the efficiency, as this can be accurately determined by temperature by colour match.* In fact, this method is of particular value when dealing with lamps of great brilliancy and high temperature such as the latest half-watt electric lamps. Such lamps are rated without candle-power measurements. The efficiency is determined by a colour match with a standard lamp of determined efficiency, and this and the total watts determines the candle-power.

The Desirable Unit for Expressing Luminous Values.

As I have stated in the first part of this paper the industry will continue to employ candle-power or some unit to state the luminous value of a lamp where it is required, as such values are necessary to express the efficiency of a lamp. It will be pertinent, therefore, to consider what is the most desirable unit for expressing the luminous value.

Shall it be the candle-power, or the lumen? Without going over the theoretical points for and against these units, so well covered in Mr. Trotter's paper and the discussion at the meeting of this Society on May 21st, 1914, I should like to give some practical reasons which appear to me to bear on the question as far as electric glow lamps are concerned.

The same reasons stated in the first part of this paper, which led to the substitution of candle-power by total watts as the practical size rating of electric lamps, will, in my opinion, lead (and are already leading) to the adoption of the lumen in place of candle-power where it is necessary to express the luminous value.

The fundamental requirement is a *definite* unit which shall always mean one definite thing. This the lumen is and the candle-power is not. We have already indicated the many variations of candle-power there are in use, the mean horizontal, mean spherical,

* See paper before The Physical Society of London, by C. C. Paterson and B. P. Dudding, on "The Estimation of High Temperatures by the Method of Colour Identity," March, 1915.

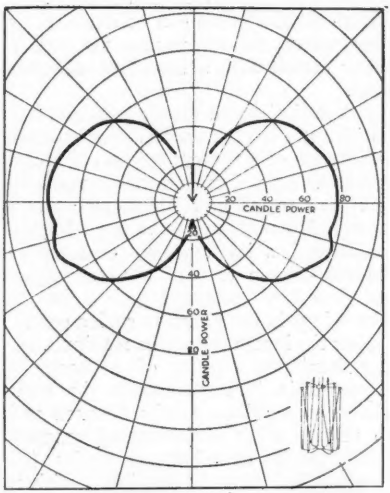


FIG. 2.—100-watt clear Standard Tungsten Lamp. Light distribution of bare lamp, in vertical plane.

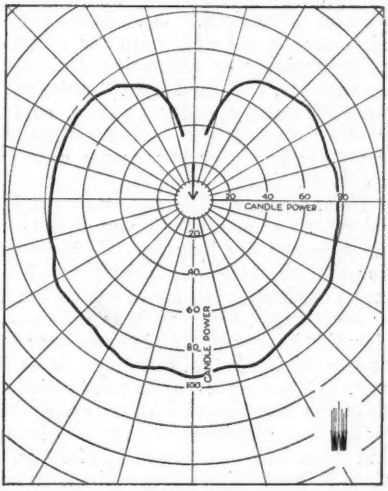


FIG. 4.—100-watt Stereopticon Lamp. Light distribution of bare lamp, in vertical plane.

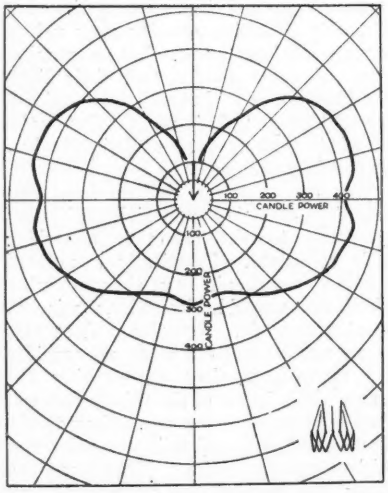


FIG. 3.—300-watt Half-watt Lamp. Light distribution of bare lamp, in vertical plane.

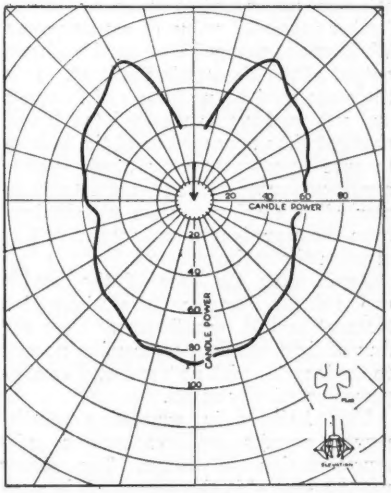


FIG. 5.—100-watt Spiralised Filament Lamp. Light distribution of bare lamp, in vertical plane.

Distribution of Light from typical Metal Filament Lamps.

hemispherical upper, and hemispherical lower, and the candle-power values in different directions, &c. Such complications do not arise with the lumen. In determining or expressing efficiency, for example, the usual term " watts per candle " raises a query at once, as to what variety of candle is meant—whereas watts per lumen or lumens per watt is wholly definite.

Then, again, the desirable unit should not permit of manipulation or alteration of apparent value by reason of change in shape of the luminous body (lamp filament) or through the use of any external or accessory devices, such as reflectors. Now this has been found in experience to be the chief defect of candle-power as a unit. Numerous examples can be given. Take the filament of a lamp, giving 16 (horizontal) candles in the ordinary lamp and shape it in a horizontal grid form and place it in an onion shape bulb and note the large increase in candle-power when measured vertically. Frost the glass of the upper part of the bulb and note the further increase in candle-power. Silver this same upper surface and note the still further increased value of candle-power. We have not changed the actual luminous output of the filament in the least. It is the same section and length of filament, and yet we have so manipulated it and changed the upper surface of the bulb as to give apparently very much greater candle-power values, as the term " candle-power " is employed, than we obtained from the same length and section of filament in the ordinary lamp.

Again, take the case of the double cap tubular lamp with straight line filament backed by reflectors. Here the flux of light is all in a direction normal to the length—with no " end-on " candle-power practically at all.

This latitude in expressing candle-power permits and encourages misrepresentation in lamps. The writer noted a case of it this past week in a so-called half-watt lamp of hitherto unknown make. This lamp was found not to be a gas-filled lamp at all—only an ordinary vacuum lamp—with a horizontal filament of spiralised wire placed in a round bulb with its upper half opal coated. The effect of this combination made the lamp look brilliant and gave an increased downward candle-power value, sufficient to justify calling it a half-watt lamp.

Here the deception can be detected by temperature measurements, through a colour match with a bona-fide half-watt lamp.

The variations in candle-power values in different directions with different kinds and shapes of reflectors are an old story. The same light flux (lumens) is made to yield now to 50, now 100, here 500 and there 1000 candle-power values. Such a condition has its extreme example in the well-known case of the searchlight and even Mr. Trotter, I believe, has to take refuge in the lumen in such a case.

Now the lumen cannot be manipulated. The luminous output of a lamp as expressed in lumens remains the same whatever the shape of the filament and no matter what variations of external arrangements or what accessories (reflectors, &c.) may be employed with it (excepting of course the absorption losses in the accessories).

The importance of this point will be appreciated when we consider the large variety of filament shapes employed in modern lamps and the exceeding difficulty of trying to assign candle-power values to many of these lamps. Let us examine some of these shapes and their light distributions, as shown in the plates herewith (Figs. 2, 3, 4 and 5). Surely the use of the lumen recommends itself when we consider such cases.

The candle-power suffers from the infirmity of being materially different according to the direction at which it is measured. Practically a unit of candle-power should have the same value whether measured horizontally, vertically, or at any angle. Actually it does not, as we readily find out when we consider the spherical surface surrounding the lamp. This is one of the things that will always be more or less mysterious to the layman and that assists in deception and misleading information. Even those who know the subject fully, find it very difficult to judge properly between the merits of different light distributions in the various zones.

This point is exemplified in the following geometrical diagram (see Fig. 6), where the same total flux of light is given in different light distribution circles.

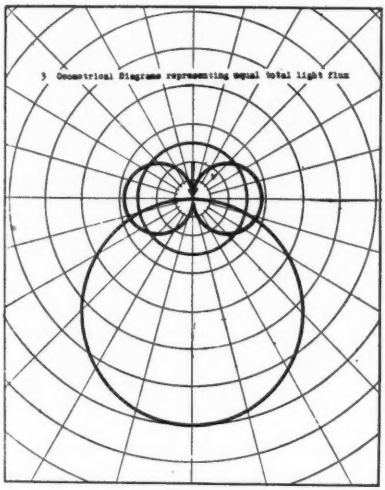


FIG. 6.—Ideal curves, showing same total light flux in various forms of light distribution. (Note the apparent large increase in lower circle as compared with the other curves.)

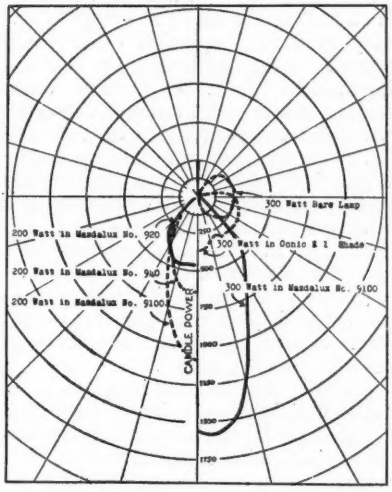

300 Watt Bare Lamp
200 Watt in Mandalux No. 920
300 Watt in Conic S I Shade
200 Watt in Mandalux No. 940
300 Watt in Mandalux No. 9100
200 Watt in Mandalux No. 9100
CANDLE POWER

FIG. 8.—Variation in apparent candle-power values of a 300-watt lamp through use of different reflectors.

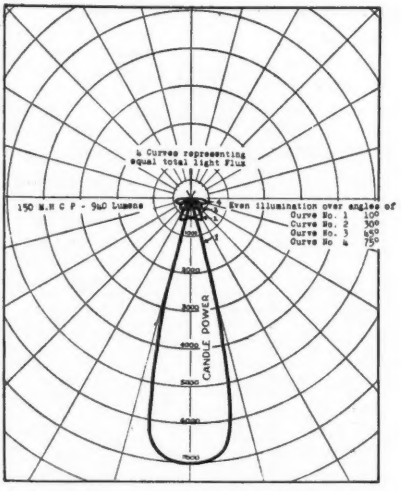

4 Curves representing equal total light Flux
150 M.H.C.P. - 940 Lumens
Even illumination over angles of
Curve No. 1 10°
Curve No. 2 30°
Curve No. 3 45°
Curve No. 4 75°
CANDLE POWER

FIG. 7.—Diagram showing how, in an extreme case, same total light flux may be distributed so as to show very misleading values of apparent candle-power. Notwithstanding its far greater area, the flux of light represented by the large curve (1) is the same as that represented by the three very small ones (2, 3, and 4).

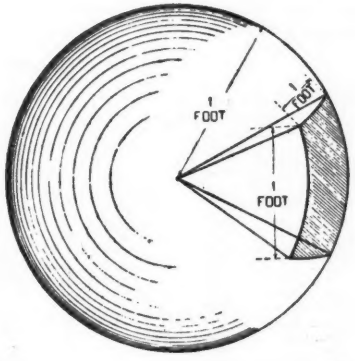


FIG. 9.—Diagram illustrating the nature of the lumen.

The same point is shown in Figs. 7 and 8, where the same total light flux (lumens) is altered by the use of reflectors to give very misleading apparent candle-power values. These diagrams are striking illustrations of the confusion of values under a candle-power rating. This latter point and the preceding point regarding the manipulation of unit values are further emphasised when we consider the great variety of distributions obtainable with reflectors and enclosing glassware. The design of modern reflectors has been carried to a point of great elaboration.

(Here slides were shown illustrating the greater variety in the light distribution from various reflectors and bowls of modern scientific design.)

Modern lighting methods, such as indirect lighting, distribute light flux in the upper hemisphere on to the ceiling for re-distribution to the area beneath—

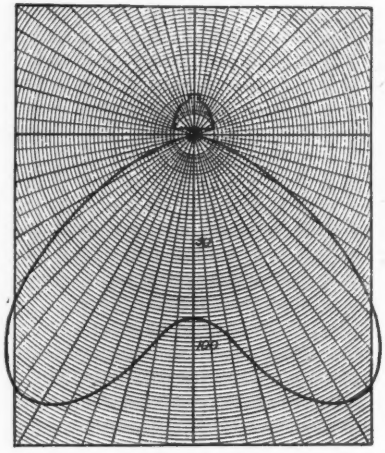


FIG. 10.—Distribution Curve of typical reflector.

TABLE III.

CORRESPONDING RECORD SHEET OF REFLECTOR (SEE FIG. 10), SHOWING LUMEN VALUES IN THE VARIOUS ZONES.

Reflector No. 555.

Reflector X-RAY No. 555.
Lamp Mazda 5-21-E clear Watts 60·0.
Calculated by J. A. H.

Holder 2¼ in. form o.
Volts 110·0.
Test No. CW-9.

LIGHT FLUX DELIVERED.

Zone.	Mid-Zone. Angle.	Mid-Zone. C. P.	Lumen Constant.	Lumens.	Zone.	Lumens.	Per Cent. of Bare Lamp Flux.
		per cent.	per cent.	per cent.		per cent.	per cent.
0— 10°	5°	92·6	·0954	8·8	0 — 10°	8·8	1·7
10°— 20°	15°	117·0	·2834	33·1	0 — 20°	41·9	8·0
20°— 30°	25°	145·0	·4630	67·2	0 — 30°	109·1	20·8
30°— 40°	35°	153·0	·6280	96·1	0 — 40°	205·2	39·1
40°— 50°	45°	130·0	·7740	100·5	0 — 50°	305·7	58·2
50°— 60°	55°	79·6	·8970	71·5	0 — 60°	377·2	71·9
60°— 70°	65°	29·9	·9920	29·7	0 — 70°	406·9	77·6
70°— 80°	75°	6·3	1·0580	6·7	0 — 80°	413·6	78·9
80°— 90°	85°	—	1·0910	—	0 — 90°	—	—
90°—100°	95°	—	1·0910	—	0 —100°	—	—
100°—110°	105°	—	1·0580	—	0 —110°	—	—
110°—120°	115°	—	·9920	—	0 —120°	—	—
120°—130°	125°	—	·8970	—	0 —130°	—	—
130°—140°	135°	—	·7740	—	0 —140°	—	—
140°—150°	145°	—	·6280	—	0 —150°	—	—
150°—160°	155°	—	·4630	—	0 —160°	—	—
160°—170°	165°	—	·2834	—	0 —170°	—	—
170°—180°	175°	—	·0954	—	0 —180°	—	—
					60°— 90°	—	—
Total Lumens of Bare Lamp				525·0	90°—120°	—	—
Total Lumens of Lamp with Reflector				413·6	120°—180°	—	—
Efficiency				78·9			

NOTE.—Lumens = Lumen Constant × Candle-Power.

September 1st, 1913.

a character of lighting to which the flux of light idea is particularly applicable. Similarly in semi-indirect lighting with luminous bowls, the light is distributed in the upper hemisphere with ceiling reflections and diffused in part in the lower hemisphere—the effects varying according to the shape of the bowl, the character of glass and positions of the lamps in the bowl. The practical point after all is that lamps are not used bare but in some form of reflector, globe, or bowl fitting; it is not the effect of the lamp alone that counts.

These various conditions, it seems to me, will result in causing the lumen to be used more and more as the unit for the definite expression of the luminous value of lamps and lighting. A great deal of the objection to the lumen is due to the fact that it is a new unit that has hardly come into the experience and practice of very many people in Great Britain. This is not, however, a serious objection, as the unit is easily comprehended and can be readily expressed just as the ordinary candle-power is. The value in lumens of ordinary incandescent lamps is practically ten times the mean horizontal candle-power, *i.e.*, 16 candle-power lamps would have a value of 160 lumens. (This arises as follows:—The mean spherical candle-power of an ordinary incandescent lamp is approximately 0·8 times the mean horizontal candle-power. To convert mean horizontal candle-power into the total flux of light in lumens we must therefore multiply by:—$4\pi \times 0{\cdot}8 = 10$ approx.).

The diagram given in Fig. 9 illustrates the nature of the lumen. The lumen is, therefore, of the same order as candle-power, except that the lumen takes into consideration the flux of light over a given zone or solid angle, whereas a candle-power, properly understood, states only the value along a single line in any direction.

It would be of value to detail here the application and use of the lumen in practical illumination calculations, but this can be better treated in a paper by itself, which I hope may be presented at some subsequent meeting. It only needs to be stated that lumens provide a very convenient and practical method of calculating illumination, the following terms being conveniently employed in such calculations:—

EFFECTIVE LUMENS.

The total luminous flux incident on the working plane is called the effective lumens. It may be obtained by multiplying the area of the working plane by the average illumination in foot-candles. The

TABLE IV.

LUMEN DATA FOR METAL FILAMENT (TUNGSTEN) LAMPS, OF SIZES AND EFFICIENCY STANDARDS IN GREAT BRITAIN, JANUARY, 1915. VOLTAGE CLASS, 100—130.

Size of Lamp in Total Watts.	Initial Lumen Values at various Utilisation Efficiencies.																	
	Total 1·00	0·65	0·60	0·55	0·50	0·45	0·40	0·36	0·34	0·32	0·30	0·28	0·26	0·24	0·22	0·20	0·15
20	110	71·5	66	60·5	55	49·5	44	39·6	37·4	35·2	33	30·8	29·6	26·4	24·2	22	16·5
30	250	162·5	150	138	125	112	100	90	85	80	75	70	65	60	55	50	37·5
40	330	214·5	198	181·5	165	148·5	132	118·8	112·2	105·6	99	92·4	85·8	79·2	72·6	66	49·5
60	500	325	300	275	250	225	200	180	170	160	150	140	130	120	110	100	75
100	900	585	540	495	450	405	360	324	306	288	270	252	234	216	198	180	135
150	1500	975	900	825	750	675	600	540	510	480	450	420	390	360	330	300	225
250	2000	1300	1200	1100	1000	900	800	720	680	640	600	560	520	480	440	400	300
400	4000	2600	2400	2200	2000	1800	1600	1440	1360	1280	1200	1120	1040	960	880	800	600

expression "foot-candles per square foot per watt" can be more simply expressed "lumens per watt."

EFFICIENCY OF UTILISATION.

The effective lumens expressed as a per cent. of the total lumens emitted by the lamps is called the efficiency utilisation. This term is entirely independent of the lamp efficiency, and is frequently called the net efficiency. It depends essentially upon the nature and colour of the walls, &c., and the amount of light reflected therefrom.

Fig. 10 and Table III. contain a simple photometric record sheet of a reflector with the values of light flux expressed in lumens given in the various zones in the form in which it is desired and employed for illumination calculations.

In Table IV. are given the values in lumens of standard (vacuum) tungsten lamps at the efficiencies at present supplied in Great Britain.

DISCUSSION.

Mr. C. H. WORDINGHAM said that this subject had been one of the keenest controversy for a considerable time, and had now reached a really critical stage. We had almost got to a deadlock in the matter, and those who were interested sincerely wished that there should be an effort made to arrive at a compromise, or, at all events, that some common ground should be found upon which to work. He wished it to be clearly understood that he approached this subject entirely from a general point of view, and not from that of a Government official. The question should be looked at broadly and not from a departmental point of view, which was apt to be narrow; he dealt with it on its merits. This matter might be looked at from three aspects; first there was the manufacturer, secondly the supplier of energy, and thirdly the consumer, that is, the general public. Taken collectively, manufacturers were strongly in favour of rating in watts, but taken individually, with few exceptions they did not seem to care very much about it. The central station man appeared to be dominated by a fear that he was going to be handicapped in his competition with other illuminants, and preferred to mystify a consumer and tell him he was getting a lamp of so many watts, notwithstanding the fact that this had no possible connection in the mind of the consumer with the light which the lamp gave. The central station man also thought that by adopting the watt rating he was going to induce the consumer to keep the watts constant, and to raise the candle-power, and so keep his account constant. That again was an extremely shortsighted view. If the central station engineer desired to displace other illuminants he must do so by competing in price. If the cost of electric lighting were reduced, its field would be widened enormously. He would like first of all to attack the subject from the point of view of *not* rating in watts. To tell a consumer that he had a lamp of so many watts was equivalent to telling a man that he was to be given a pint to drink, without telling him whether it was to be water or brandy. Mr. Willcox and those who thought with him as the exponents of watt rating regarded the matter from the point of view of the watts input. This would be permissible if the lamps always had an efficiency of 100 per cent., but they had not, and therefore it was necessary to know the input in watts and the output in light. Nobody would think of rating a motor in watts input. With regard to candle-power, Mr. Willcox had been a little unfair in using the term candle-power without any qualification whatever. It was perfectly true that people talked about a lamp of so many candle-power, but in doing so those who advocated a candle-power rating always assumed that the mean horizontal candle-power was understood. This was not always mentioned every time, but it was always implied. It was impossible to tell what a lamp was doing without a candle-power measurement, and therefore we must come back to photometric measurement, whether we rated in watts,

lumens, or candle-power or anything else. It was impossible to know anything about the lamp unless one knew the watts put into it and the candle-power it gave out in every direction. He could not see that it was easier to rate in lumens than in candle-power, as we must come back to the mean spherical candle-power or the total flux of the light. There was a great deal to be said in favour of lumens, but this was only in fact rating by candle-power, though perhaps in a more convenient way. He had a perfectly open mind as between rating in candle-power and in lumens, but he most strongly and emphatically protested against rating in watts input.

The CHAIRMAN, while agreeing with Mr. Wordingham that we had come to a deadlock in this matter, pointed out this Society, owing to its representative membership—including makers and users of lamps, central station engineers, and others interested—was in a specially favourable position to deal with the subject, in a broader, unbiassed manner.

The questions to be determined were, "What should the lamp-maker mark on the lamps?" and "What is it the user chiefly needs to know about its performance?" He thought that the information marked on the lamp should be an adequate description of the lamp's capabilities as a lighting unit. If the present methods of rating and marking were not satisfactory in this respect, then the manufacturers should be told what was wanted and, in their turn, would consider how these requirements could be most easily met. He hoped that the discussion would proceed on these lines and that it would suggest a useful basis of agreement.

A number of written communications had been received, and he would ask the Honorary Assistant Secretary to read these before the discussion proceeded further.

Mr. DOW read communications from Professor SILVANUS P. THOMPSON, Mr. F. W. GOODENOUGH, Mr. E. ALLEN, Mr. HAYDN T. HARRISON, Mr. W. J. A. BUTTERFIELD, and Mr. GEO. KEITH. (See pp. 180–185.)

Mr. C. C. PATERSON agreed very strongly with Mr. Wordingham, that all apparatus should be rated in terms of output, viz., what it is intended to do, and thus on broad principles some rating in terms of light output ought to be adopted for lamps of all kinds, gas, electric, and oil. Information as to the input to a lamp was also wanted, but he did not desire to express any opinion, at this stage, as to whether "round numbers" of input or "round numbers" of output should be adopted.

It had been suggested that lamps have such varying distribution of light that it is very difficult to rate them in candle-power at all, and that consequently we should rate in watts or cubic feet of gas. He had never been able to follow that argument at all. Prof. Silvanus Thompson seemed to adopt the same view when he said that lamps changed in candle-power during life, and that therefore they should be rated in something else which did not change, viz., watts. The watts, however, had little to do with the amount of the light output, witness the difference between the carbon, the vacuum tungsten and the gas-filled tungsten lamps. He submitted, therefore, that the suggested watt rating as a fundamental rating for light sources was not a rating for *light sources* at all, and even intended as a rating for lamps as *energy consuming devices*, was applicable only to electric lamps, whilst oil and gas lamps must be rated on different lines altogether.

Difficulties might arise in arranging exactly what candle or flux rating should be used, but they should decide to employ something which was proportional ot the light giving power as a rating. If it were decided to adopt some form of candle-power or flux rating, what was it going to be? We must be clear on what the lamps were being rated for. It would of course be very desirable if it could be said that a certain lamp had a certain rated candle-power which could be used in all calculations to find out what the illumination would be at any point in the neighbourhood of the lamp. Lamps were not, however, ideal point sources, and it was clearly impossible to expect this. They varied in the distribution of their light, and therefore we must give up

the idea of rating being a rigid guide to the illumination at any point. He preferred, as a rule, to look upon the rating as a gauge of the total amount of light given out by a source, and on this basis there should not be difficulty in arriving at a system of rating for all illuminants.

Prof. J. T. MORRIS agreed that it is desirable to rate in output, not in input. On every lamp, as far as possible, the output and input should be marked, much in the same way as in the early days of the carbon filament lamp, the voltage, candle-power, and amperes were marked, together with a letter which gave the efficiency in watts per candle. The author agreed that it was desirable that additional particulars should be furnished to illuminating engineers, such as polar curves of light distribution, to enable them to plan lighting installations. A case had recently occurred in which he had had difficulty in deciding whether to adopt the new "Downlite" Lamp owing to lack of sufficient information, and the only way he could tackle the problem was to secure one of the actual lamps and measure the illumination at certain distances below it. In this way he was able to advise as to the right number of watts needed for the rooms in question; the result was that the watts had been reduced to about two-thirds, whilst the illumination on the working plane had been appreciably improved. He suggested that it might be worth while lamp manufacturers supplying to those interested, not only the polar curve of the lamp itself, but the polar curve of the lamp with the fitting considered most suitable for use with it. Further, it would be valuable to have the illumination figures for a horizontal surface, say 8 feet below the lamp, or better still at two different distances; whilst for high-pressure gas and arc lamps a similar set of figures, say, 20 feet below the sources of light, should be given. From these figures it would be easily possible to predict the illumination in other cases. With regard to the use of the symbol "I" to indicate the mean spherical candle-power, he doubted whether this was desirable, since only in the last few years, and not without some difficulty, had the symbol "C" for current been changed to "I," and if this symbol were also to be used for illumination confusion would inevitably arise.

Mr. J. MACINTYRE expressed himself strongly in favour of candle-power rating, and agreed that watt rating was no rating at all. One might just as well rate by the size of the bulb. All machinery was rated on the horse-power it gave out. It might be easier for the makers to rate in watts, but as the efficiency of the lamps increased he thought the public would call for a more convenient rating, and one which really gave them some idea of the output in light. Station engineers were very much concerned with steam consumption, and what station engineer would accept an engine which was rated on the amount of steam used per hour? But after all it was not the station engineer who was principally concerned with the lamp, but the consumer.

As to the additional particulars which could be furnished to illuminating engineers this was not a very difficult point. Curves were prepared in estimating from the combination of the lamp and shade. In addition to a polar curve it was usual to prepare a curve which gave the illumination 5 ft. down from the lamp and on a horizontal plane of varying diameter. These two curves were used for comparisons of different combinations of lamps and shades. In specifying interior lighting it was quite possible to specify illumination in so many foot-candles. In cases where the rooms were fitted up with furniture, or in stores, libraries, &c., this might not be so easy to apply to the room as a whole, but in those cases the foot-candle basis must be applied to individual lamps placed in individual positions.

Mr. J. Y. FLETCHER said he would like to correct an impression which most speakers seemed to have, namely, that the makers desired to rate in watts only. He had never heard of such a suggestion from manufacturers. At present they gave the watt consumption and the watts per candle-power consumption as well as the candle-power. Further, from his own experience, he knew that some

manufacturers' catalogues would contain, in future, polar curves of light distribution of each type of lamp.

The CHAIRMAN asked if the candle-power was marked on the lamps.

Mr. FLETCHER said it was not, but lamp makers had always expressed their willingness to do so, but their contention was that it did not instruct the purchaser one whit whether the lamp was marked with 30 candle-power or 30 watts; the purchaser did not know which was true. In saying this he did not mean to suggest that the mark was untrue, but it was impossible for the purchaser to know whether the marking on the lamps was the true marking. If it were in watts only the purchaser could buy a watt-meter for 30s. and test it for himself, but if it were marked in candle-power he would have to buy a photometer which might cost £30 and when he got it would not be able to use it.

The CHAIRMAN asked if lamp-makers would be satisfied to have each type of their lamps certified by the National Physical Laboratory, and a report issued specifying the consumption, candle-power, and polar curve of light distribution.

Mr. FLETCHER: Certainly.

The CHAIRMAN said if this were adopted by all makers it would put all their catalogues on a comparable basis.

Mr. FLETCHER said he would be quite agreeable to this and, further, to put the candle-power not only in the catalogues but on the lamp itself.

Mr. THOMAS E. RITCHIE said that as one largely interested in the arc lamp in its various forms, he would be exceedingly sorry to see the watt rating—or any other system in which the *input* as distinct from the *output* was the determining factor—introduced. It was only when one considered such a rating as applied to arc lamps that one realised to the fullest extent how extremely absurd and misleading it might become.

The variable factors were considerably greater in arc lamps than in many light sources. A lamp taking, for instance, 460 watts, might actually develop anything from 1,736 to 351 mean spherical candle-power (21,821 to 4,412 lumens), according as it happened to be of the flame, open, or enclosed variety, and again according to the number and character of the globes used upon it and the quality of the carbons with which it was trimmed.

By any method of input rating only each of these lamps would appear to be of the same value. The most inefficient and unsatisfactory article would be placed upon exactly the same plane as the most efficient and most satisfactory, and the user would stand a very good chance of being seriously misled. Further, such method would inevitably tend to a reduction in efficiency, as the stimulus of healthy competition would more or less disappear.

He disagreed entirely with the statements of the author to the effect that arc lamps were now sold on the basis of an input rating (*i.e.*, on the amperes for which they were wound or the watts which they consumed) rather than upon the output yielded. They were certainly not so purchased by the discriminating buyer, and in these days of more general, and more advanced, technical education and methods of thought most large buyers, at all events of arc lamps, *were* exceedingly discriminating.

His experience was that purchasers of lighting devices were day by day insisting, to a greater extent, upon being provided with definite figures as to the input of energy, the output in light, and the cost of maintenance, and he must say that he had found very many of them quite capable of distinguishing between the various candle-power ratings and of making very close and accurate comparisons.

It had long been the practice of the Company with whom he was associated to give the rating of their arc lamps in mean hemispherical candle-power, either upper or lower, as the case might be, with when necessary a reduction factor for mean spherical candle-power. In the case of those who desired it, and could utilise the information, a polar curve of the complete unit was also supplied, and it was, he thought, only by continuing

to make use of all these factors, and by a willingness upon the part of manufacturers to furnish data and if necessary to *guarantee* the figures given, that accurate and scientific work could be carried on.

He had no objection to the output being rated in lumens if desired; on the contrary, the fact that the lumen rating did not lend itself to any confusion or inadvertent inaccuracy, and had always the advantage of the lumen second as a definite unit, would doubtless be of considerable value to illuminating engineers. He thought, however, that the mean spherical candle-power was more acceptable to the British mind, and was of the opinion that it would be a very long time before it was superseded by anything else.

Mr. J. G. CLARK showed several slides illustrating the various candle-powers that can be attributed to a lamp if no mention is made of the angle referred to. As one representing a gas company he had frequently to advise consumers as to the most suitable lamp to adopt for a particular purpose. He had for a long time advised his principals to accept a complete polar curve together with the consumption as the best expression of the photometric value of a lamp. From such a curve it was possible to calculate mean spherical or hemispherical values in candle-power or lumens, or anything else, and what is of great importance practically, one could calculate heights and spacing ratios for installations.

In dealing with gas lamps it was usual to speak of the efficiency in terms of a standard gas consumption, namely, one cubic foot per hour. It occurred to him that a new term might with advantage be coined to represent the standard rate, and he suggested the word "cubour" to represent one cubic foot per hour, so that the consumption of a lamp would be spoken of as so many cubours. It is usually understood that the consumption when simply stated in cubic feet means that amount every hour, but it would be a good thing to have a special term which could not be misunderstood.

Or we might follow the example of our electrical friends and immortalise Murdock the inventor of gas-lighting just as they have immortalised Watt. Watt and Murdock were contemporaries. The watt is the unit *rate of consumption* of electricity; then let the Murdock be the unit rate of gas consumption. The expression of so many Murdocks as the consumption of a gas lamp might seem quaint at first, but it was, he thought, worth consideration.

Respecting the specification of definite illumination values by architects and engineers, he saw no difficulty in this: it was, in fact, in his opinion desirable that this should be done, so that those who had to carry out the job could do it in a common-sense scientific manner.

Mr. M. FOULDS said he scarcely understood why there should be any controversy on the matter. He certainly thought that one should know the candle-power of a lamp, and also its efficiency. This fixed the consumption.

Mr. LE MARECHAL, as a manufacturer of lamps, said that makers generally were working towards setting down the total watts to equal the total candle-power; in other words, to work at one watt per candle. In that event it would not seem to matter which basis was adopted.

Mr. WORDINGHAM: Surely you will improve on that.

Mr. LE MARECHAL said makers hoped to do so in the future. He thought there were some advantages in working in watts, but if the public wanted candle-power marked on the lamps there was no objection to putting it there.

Mr. MULLARD said that the public at present fully understand candle-power marking, and that if any alteration were to be made the candle-power should be retained.

Mr. E. STROUD: I think that the most important point in the marking and rating of lamps is its accuracy. There seems to be legal restriction to stop a lamp-maker from marking a lamp at whatever rating he likes, irrespective of the capacity of the lamp itself. This also seems an opportune time to stop the rating of lamps in German Hefner candles,

as this rating gives the lamp a fictitious value of efficiency 10 per cent. in excess of that usually understood. Polar distribution curves of the bare source should of course be supplied, as also any information such as life, &c., of the lamp, but the polar curve of the lamp alone is not of great importance to the consumer, as nobody uses a bare lamp, but always uses some shade or reflector to shade or redirect the light. The combination naturally alters the original distribution of the bare source, so that it should be the duty of the suppliers of the whole unit to publish such curves.

This accuracy of rating lamps is of great importance when working on illumination values, which is the basis of all calculated lighting schemes. I consider that all lamps should be marked *similarly* with voltage, watts consumption, and candle-power (*which should be mean spherical*). This marking is more understandable, and would practically be the same thing as marking in lumens or quantity of light emitted. Undoubtedly the ideal method of marking lamps would be voltage, energy input, and quantity (of light) output.

Mr. R. CLAUDE BUSSELL remarked every one that evening had spoken as though gas and electricity were the only two possible illuminants. He reminded the audience of the existence of paraffin, which, long in world-wide use, could now even become a formidable competitor as a result of modern inventions. If the Council were to adopt the recommendation of the speaker who advocated that cubic-foot-hours should be known as "Murdochs," a plea would have to be advanced on behalf of paraffin for a standard in say "pint-days," which might appropriately be christened "Rockefellers." To be serious, however, he felt strongly that any standard of rating should be common to electricity, gas, paraffin, or any other illuminant that came along.

Mr. F. S. TILLEY, as a manufacturer, was not so concerned as to how lamps were judged so long as a particular measure was adopted which would enable all lamps to be judged on the same basis. It was very disappointing to any manufacturer who took a very great interest in his laboratory to rate his lamp accurately and upon sending it to different parts of the country to find it judged in totally different ways. This was a very important matter which the Society might take up, viz., to devise rules for the guidance of those who have to test lamps no matter whether electric, gas, or paraffin. There was so much discussion as to the proper method of testing lamps that it was practically impossible to get the same result from different people's tests.

Mr. J. S. Dow said that if one tried to make any kind of general scientific comparison between lamps it was necessary to do so on the basis of the input and the total output of light, *i.e.*, the total flux of light or else the mean spherical candle-power. The essential thing for the illuminating engineer to have was the polar curve. At the Optical Convention two years ago it was interesting to note how many firms started using polar curves with their exhibits, and to-day these were quite common in catalogues; whereas five years ago they were quite unusual. With this information any body could work out all the details of an installation from first principles.

Then there was the question what data should be supplied to those designing a lighting installation. There were many existing rules, such as that an 8-candle-power lamp would light so many square feet, &c., but in practice the results depended very greatly on the type of lamp and the shade adopted. A much better basis was to state the illumination on the working plane; but even that was not everything, because it was possible to get a very strong illumination on the working plane, and to neglect the lighting of surroundings. In almost all cases a certain amount of general light was needed in the room irrespective of what was wanted on the work. He suggested that we should specify both the illumination on the working plane and the total flux of light in lumens (or the mean spherical candle-power) for a given cubical space.

The CHAIRMAN (Mr. L. Gaster), in winding up the discussion, said there seems to be general agreement that the

voltage, watts, and candle-power of electrical lamps should all be marked on the lamp; and that in addition the polar curve should be available in the literature relating to lamps and lighting units, so that the expert might know what they could do in practice.

He had been very glad to find that manufacturers were agreeable to having tests of typical lamps made at the National Physical Laboratory; if all manufacturers would adopt this practice and would give the results as regards consumption and candle-power, and would furnish the requisite polar curves in their catalogues and other literature, this would at once indicate to the lighting expert in an authoritative manner what the unit was capable of doing. This was a great point gained, and, in itself, was a most useful fact to have been established by the discussion. At present fanciful estimates of the performances of lamps were apt to find their way into catalogue literature, and claims were not infrequently put forward for special forms of lamps which would not stand impartial investigation.

There was no power to make manufacturers mark on the lamp anything other than what they thought fit, and it was therefore essential that the responsible makers should agree on a general correct practice in this respect. It was naturally expected of this Society that it should use its influence with manufacturers to bring about a friendly understanding on these points and, although there were doubtless many details that would require further consideration, he thought that a step in the right direction had certainly been taken.

Mr. WORDINGHAM, briefly replying, said that the general consensus of opinion appeared to be that lamps should be rated on the basis of what the user expected to get out of the lamp, and not what he expected to have to pay for it.

Mr. F. W. WILLCOX also briefly replied. One main question, he said, seemed to have escaped attention, viz., that the results we have to-day have not been arrived at by theoretical discussions, but by practical evolution. It was natural for scientific theorists to scoff at the idea of rating a lamp upon its input, but the system had been in practical use for four or five years, had been developed by practical evolution, and was giving every satisfaction. The relation of input to output of a lamp was a very direct, simple, and invariable one, and not complicated as in the case of motors. So far as the user of a lamp was concerned, he believed it conveyed to him just as much information if a lamp were called a 20-watt lamp as if it were called a 16-candle-power lamp.

He was grateful to Mr. Fletcher for emphasising the point that there was no intention of abandoning the candle-power marking. It was easy enough to put candle-power on the lamp, but the point was, should we start with a line of sizes in fixed wattages or in fixed candle-power? At present there was a fixed line of sizes in watts in Great Britain, Canada and U.S.A., and it had proved very practicable. Every engineer knew what he had to deal with and could calculate from the wattage to the candle-power. Yet Mean Spherical Candle-power was quite a mouthful of words and it is easier to think and talk in lumens. He was quite willing to leave the question to the mercies of practical evolution which had carried the matter so far already. Practical conditions have bowled over all theories, and the points of the evening's discussion had simply repeated those raised in the States a year or two back at the time the watts rating came into use. Practical evolution had carried the day and the watts rating remained.

A hearty vote of thanks was accorded to Mr. Willcox and to Mr. Wordingham at the conclusion of the discussion.

Professor SILVANUS P. THOMPSON (*communicated*):—My view on lamp classification is this: that lamps should be *marked* with *volts* and with *watts*, and, if desired, with approximate *candle-power* (mean spherical), but that for the "ranging of standard magnitudes" they should be ranged in certain specific values of *watts*—10-watt, 20-watt, 50-watt, &c.—leaving the approximate candle-power to be such values as the makers can attain for the

particular numbers of watts. My chief reasons for this opinion are: 1. The greater constancy during life, of the *watts* of the lamp. 2. The greater ease of verifying the *watts* than of making a mean spherical photometric test.

Mr. A. P. TROTTER (*communicated*):—Some time ago, in the course of a short conversation with Mr. Gaster, he converted me from rating in candle-power to rating in watts. He met all my objections. I forget his arguments, but I have heard a full discussion on the subject and I remain convinced.

My convictions have been supported by my domestic use of "down-light" and of "daylight" lamps, for neither of which horizontal candle-power is suitable. The public who do not know much more about candle-power than they know about watts will soon learn that a watt is rather better than three-quarters of a British candle, and this is rather better than the inferior German thing called a Hefner.

In its proper place the lumen is indispensable, and I shall take refuge in it whenever it will help me in calculation or in expressing myself. But I do not think that as the fundamental unit in photometry or in the commercial rating of lamps the lumen is in its proper place. Lumens per watt is a valuable expression, and should replace watts per candle. But it can only be handled by experts, and is not fit for public use.

As regards the list of symbols, I would suggest the addition of I_h to indicate mean horizontal candle-power: also that I_ϕ is preferable to I_α as the letter α (alpha) is very apt to become confused with a in printing.

Mr. F. W. GOODENOUGH (*communicated*):—The question of rating and marking units of illumination in such a way that the user can tell exactly what he is buying is a very important one, and if the Illuminating Engineering Society can do anything effective in the direction of establishing standard methods of specifying the illuminating value of such units they will have done useful work.

At present, the buyer who is not equipped with a photometer is largely dependent on the commercial honesty of the seller, which is often widely different from his personal honesty. He is too often inclined to yield to the temptation of fighting the dishonest man with his own weapons. We want to get away from "nominal" ratings to actual ratings based upon a common standard.

In regard to points set out in the memorandum issued as a guide to discussion, I should like to make the following brief observations.

(1) I see no reason why lighting units should not be rated and marked in both energy *and* candle-power. The user wants to know what light he will get and what quantity of energy he must pay for in order to get it. If he is only told a lamp is 50 c.p. he will reply "How many watts (or cubic feet) will it consume per hour?" If only told a lamp is a 75-watt or a 2-c.ft. per hour lamp, he will at once ask "What light will it give?" The two factors energy and light are not always in the same ratio one to the other and ought therefore both to be specified.

(2) I do not consider that any necessity exists for the introduction of the lumen basis in lieu of the candle-power basis with which the public is familiar. All that is required is a standardisation of what is meant by the candle-power of a lamp.

(3) In defining what is meant by candle-power, I am in favour of mean spherical candle-power, whilst for the selection of types of lighting unit for various purposes the illuminating engineer needs to have polar curves obtained from the complete unit as it would be used. These would give him the necessary information as to candle-power in particular directions and would enable him to ascertain the mean lower hemispherical candle-power, &c., but it would be more convenient if more data were given as well as the polar curves. It is obviously desirable to adopt recognised symbols as suggested; but the signs for upper and lower hemispherical candle-power should be open and not closed curves, to prevent possibility of confusion in manuscripts or small print. It appears quite practicable to adopt foot-candles on the working plane as the basis for specifications for interior lighting, but the illuminating engineer will of course require from the supplier of the installation a guarantee

as to the hourly consumption of energy required to give *and maintain as a minimum* the specified illumination.

A difficulty obviously exists in the marking of a light unit such as a gas lamp which is composed of several detachable parts—burner, injector, mantle, globe, reflector, &c.—the correct combination of which is required to give the normal lighting efficiency of the unit. The rating of such a unit must necessarily be stated to be subject to the replacement as and when necessary of the mantle by one of similar quality, just as the rating of an electric incandescent lamp must be stated to be subject to its replacement as soon as the filament has become depreciated in lighting power. In other words, the rating of all lighting units must be recognised to be in relation to their efficiencies when new. The particular point that should be emphasised is that if users wish to obtain from the energy they consume the maximum lighting efficiency, they should go to their gas undertaking for mantles which are bought on a quality first basis and submitted to stringent tests, or to their electricity undertaking for advice as to the purchase of lamps, and not ruin a good installation by using "cheap" mantles or filaments to replace those which were capable of giving the specified candle-power.

Mr. E. ALLEN (Liverpool) (*communicated*):—I fear that the time has not yet arrived for a standard specification for burners and mantles, as the conditions of pressure and composition of gas are not uniform throughout the country.

At the present moment we have no specification for burners, but have lately tested a large number of burners with the object of finding out which gives the most satisfactory results. The variable effects we have had to contend with are pressure, specific gravity, and composition of the gas. Any and all of these conditions have a very determining influence over the Bunsen flame, and we have ascertained that the best practical burner is perhaps one of the simplest and the cheapest. Burners which have interchangeable parts and which are supposed to be suitable for a special gas, have not proved satisfactory. Swing burners with bayonet fittings perhaps lengthen the life of the mantle, but if they do not hang perfectly vertical they become an eyesore. Burners which allow the products of combustion to mingle with the primary air, do not give a very good efficiency. The uses of wire gauzes in burners are not successful, because they, like metal nozzles, burn away. The injector plate should not be a thin stamping, but at least a thirty-second of an inch thick so that the holes may be of such a form that a control of the jet is obtainable.

Mantles are purchased by my Company on results from experiments. Tests are made as follows: Three mantles are chosen out of a parcel, one is tested for illuminating power, the second for hours of endurance, and the third is placed upon the shocking machine and tested for strength. In reference to the candle-power, we have made tests of lamps by which we have obtained polar candle-power curves, this result being largely governed by the use of a reflector as well as the position of the mantle inside the lamp.

It appears unnecessary to express the candle-power of a lamp in mean spherical or mean lower hemispherical candle-power. So many factors control the average hemispherical result which may be detrimental to this term. The lamp may be rated at its maximum candle-power on a certain angle. In any case a standard candle-power should be maintained for all illuminants.

Mr. HAYDN T. HARRISON (*communicated*):—In my opinion to rate the value of light sources in anything but light units is not only illogical but is also often the cause of serious ophthalmic troubles. For instance, a layman may buy two 10-watt electric lamps, one of which, being of a carbon make and high voltage, gives 2½ mean spherical candle-power, and the other one, being tungsten filament, gives 8 mean spherical candle-power. Eight candle-power on the usual table fitting will give satisfactory results for reading or writing; 2½ candle-power under the same conditions may cause eye strain due to poor illumination, whereas if the lamps had been rated according to their light-giving value this would not have occurred. I do not think it is essential that this light

giving rating need be closer than, say, 5 per cent. or even 7½ per cent., to the actual rated figure, and therefore, even if the lamps are marked in watts or cubic feet per hour, as the case may be, they should also bear marking relating to light-giving value.

As regards whether light sources should be rated in candle-power or lumens, I am inclined to favour candle-power, provided the symbols in paragraph (4) or some such symbols are adopted. This allows the average person to understand in which direction the maximum light will be obtained, and he can adapt the position of the lamp accordingly.

As regards the adoption of lumens or candle-power—the term candle-power has become so firmly fixed in the minds of people in this country that I think a change from candle-power to lumens would prove nearly as difficult as a change from the duo decimal to the decimal system of coinage.

As regards paragraph (5), I have found no difficulty in specifying interior lighting by giving the illumination desired on the working plane. To specify by consumption of watts or gas, as I have already explained, to me appears ridiculous. To specify by candle-power is simply transferring a certain amount of work from the Contractor to the adviser. It is a small detail and I must admit that in practice I have generally found it advisable to specify the actual type of lamp and reflector, but I have always specified it more as an example of what is required, in order that the best thing of its class could be adopted.

Mr. G. KEITH (*communicated*):—The present methods of rating of both gas and electric lamps leave much to be desired. Personally, I am in favour of the power of lamps being stated in terms of mean lower hemispherical value.

Mr. J. W. T. WALSH (*communicated*):—I should like to make a few remarks on the question of the specification of interior illumination by foot-candles instead of by candles per sq. foot. It will, of course, be at once conceded that the quantity about which information is really desired is illumination at the working plane. It is of no value to any one who has to read a book to know the candle-power of the lamp by which he is reading, except in so far as this affects the illumination of his book. That it is which interests him, and of course the ideal method of specifying illumination is by the unit of illumination, the foot-candle. Unfortunately, until quite recently, the direct measurement of illumination has been attended with much difficulty in practice, and the prediction of the value of illumination which would be attained under certain predetermined conditions was almost impossible. Hence arose the method of specifying a certain number of candles per sq. foot of area of the room to be illuminated, this method presenting no difficulty and giving at least a rough idea of the illumination to be expected from an installation so specified.

With the advent of the modern portable photometer, however, it would seem that the time has come to reconsider our position in this respect. The measurement of illumination is now no longer the laborious process of former days, and it is possible to obtain a very good knowledge of the average illumination in any moderate sized room (say 20,000 to 30,000 sq. feet in area) in less than an hour. This allows for about 50 observations, which should be quite a sufficient number for ordinary purposes. As to the prediction of the results to be expected from a given installation, Prof. Clinton, in his paper before this Society twelve months ago,* showed how accurate a forecast could be obtained from previous data as to the size of room, distribution, candle-power, and polar curves of the lighting units.

But in spite of all that may be urged in favour of the foot-candle, there are naturally many who will cling to the time-honoured method until they see good reason for changing, or until it has been definitely tried and found wanting. With an idea of making a comparison between results obtained by the two methods, I had the curiosity to examine the results given by Prof. Clinton in the paper to which I have already referred. It may, perhaps, be recalled that he there deals with nine widely different systems

* W. C. Clinton, *Illum. Eng.* (Lond.), VII., 189, April, 1914.

of lighting, and from the very full details of the systems used in each case and of the observed illuminations, it becomes an easy matter to compare the candles per sq. foot with the foot-candles at the working plane in each case. The results obtained are tabulated below :—

Description of Installation.	M.H.S.C. sq. ft.	Foot-candles.
1. Workshop with tungsten lamps in metal reflectors	0·45	2·5
2. Drill hall with tungsten lamps in metal reflectors	0·26	2·1 to 2·7
3. Church with tungsten lamps in prismatic glass reflectors (central area only) ..	1·6	3·0
4. Railway booking hall with tungsten lamps in prismatic glass reflectors	0·50	1·5
5. Schoolroom with incandescent gas ..	1·0	5
6. Workshop bench with local lighting ..	—	—
7 and 8. Indirect lighting	—	—
9. Machine shop with flame arcs	2·0	2·6

The above examples sufficiently indicate the probable magnitude of the discrepancies to be met with in the results given by the two methods. Calculation on a mean spherical instead of a mean hemispherical candle-power basis would probably have considerably changed the numbers given in the second column, and it is one of the objections to the candles per sq. foot method that it becomes absolutely necessary to specify the particular candle-power on which the calculations are based. The difficulties of the method are, of course, enormously increased in the indirect or semi-indirect systems of lighting now coming so much into favour. None of these objections can be raised against the direct measurement of the actual illumination in foot-candles, and it is therefore to this method, I think, that we should look for progress in the future.

Mr. F. J. HAWKINS (*communicated*) :— The subject under discussion is much broadened by the fact that different forms of light units have been under discussion. There is such a contrast in the many forms of illuminants available that the standardisation of a common rating which would apply generally to all forms presents a problem requiring much consideration.

It seems unfair criticism to accuse the manufacturer of adopting such a method of lamp rating that would most easily deceive the public as to the actual output of a unit. Heretofore (and it might even be the condition in the majority of cases at the present day) the average lamp user has undoubtedly been more interested in his lighting bill than his actual "output" in candle power ; on the other hand the illuminating engineer, whose object and aim it is to produce the utmost economy and effect from an illumination standpoint, rightly demands to know the exact light distributing power or "output" of a lamp in order to enable him to satisfactorily plan a lighting installation.

The efficiency of lamps being fairly generally known, a wattage rating would be quite sufficient ; however, a candle-power marking representative of the M.H.C.P. or M.S.C.P. would certainly be more straightforward for the comparison of different light units, but even this would not be sufficient for the illuminating engineer. Summing up the various arguments put forward—I think the marking of lamps would be just as satisfactory from a public standpoint whether marked in Watts or C.P., but spherical distribution curves of all types of lamps should be available for the benefit of the illuminating engineer.

Mr. H. STANIFORTH (*communicated*) :— The importance of a universal method of rating lamps is undeniable, but at the same time it presents many practical difficulties. Referring more particularly to gas units, we find several features in which these differ from electric lamps when considered from the point of view of rating. In the first place, a casing of some kind is essential in most gas lamps, and a certain amount of reflection is obtained therefrom, if the inside of the casing is enamelled or of polished metal. Then, again, it is generally necessary to use some type of glassware to protect the mantle from draughts, and though

this may be clear glass it is possible to vary the distribution of the reflection on to the surface of the glass, or by refraction. In the case of lamps of the type used for the outside lighting of shops, it would be necessary to test these complete, which would entail the blackening of all reflecting surfaces.

Different results are obtained by varying the arrangement of the mantles in those lamps where clusters are used, but of course it is the business of the manufacturer to determine the best arrangement. It should therefore be possible to rate gas lamps as though they were without reflectors, but it will be understood that if a test were taken at or about the horizontal with a cluster lamp, a much lower result, stated, say, in candle-power per cubic foot of gas, would be obtained than in the case of a single mantle lamp; but I fail to see of what interest or use this value can be to the illuminating engineer, as distinct from the lamp manufacturer, when it is considered that in use the lamp will in all probability be fitted with a reflector, and also glassware, which has a decided effect upon the light distribution.

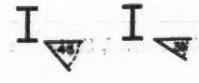
For instance, a bare lamp might be rated as a 100 c.p. unit, but that value would not be of any use to the illuminating engineer if the complete unit carried, say, a concentrating reflector which so altered the distribution that there was equivalent to 300 c.p. directly beneath the lamp, and all light cut off at 45°. What in my opinion conveys the most information to the illuminating engineer is a polar curve showing the light distribution, along with the gas consumption and pressure—in the case of the gas lamp—when the curve was taken.

Take the case of low pressure gas lamps for street lighting. Here the greatest difficulty is to obtain sufficient illumination at a point mid-way between the lamps, and it is only by using suitable reflectors that a reasonable illumination is secured at that point. I quite fail to see what useful purpose would be served in the case of that kind if it were known that the bare mantle gave, say, 150 c.p. at some particular angle. There always appears to be this same difficulty when the output of a lamp is considered in lumens or any other aggregate value which does not convey any information with regard to the distribution of the light. The total flux of an illuminant may be quite satisfactory, and yet the distribution may be defective for a particular purpose. For instance, it is quite possible to get a dense shadow, say, directly beneath the lamp, and yet from a flux of light point of view the unit might be quite satisfactory.

For the same reasons I do not think that stating the value of lighting units in terms of mean spherical candle-power, mean hemispherical candle-power, or candle-power in a particular direction, conveys the information that is required by the illuminating engineer when laying out a lighting scheme.

I quite agree that it is much better to state the illumination on a working plane in foot-candles rather than working on a wattage or consumption of gas basis, and certainly it is to be preferred to the candle-power per square foot of floor area, irrespective of the requirements at particular points. It is quite a simple matter to prepare tables or curves giving the c.p. required at any angle and at a particular distance from the plane to be illuminated for an illumination of, say, 1 foot-candle on a normal, vertical or horizontal plane, and to work back very readily from these figures the illumination with any other state of conditions. Such values as mean hemispherical c.p., total flux, &c., would be of use if all lamps had similar distribution curves, but with the multitude of reflecting arrangements on the market, each giving a different light distribution, I think it is preferable to work from the polar curve basis, provided the conditions under which the curve is obtained are also stated.

Mr. W. J. A. BUTTERFIELD (*communicated*):—The symbol I_α should be consistent with $I_\circ$ and $I_\circ$, *i.e.*, should represent the candle-power at an angle α with the *horizontal*. I should prefer a symbol which would indicate clearly that this is the case, *e.g.*:—



to indicate angles of 45° and 30° below the horizontal.

SEARCHLIGHTS IN THE POLISH CAMPAIGN.

ACCORDING to the official Russian report searchlights played a very important rôle in recent operations in Poland. It is stated: "The Germans under cover of darkness attacked in compact masses, but the enemy, lit up by our searchlights, were decimated by our fire."

In such cases, clearly, "light on the object, not in the eye," is the principle adopted, and the searchlights, besides directing the Russian fire, acted as a species of glare to their opponents.

STATISTICS ON STREET LIGHTING.

A PAPER on street lighting was recently read by C. B. Babcock before the Pacific Coast Gas Association.*

The author gives some statistics showing the development in the respective quantities of gas and electric lamps in various American and Continental cities.

He remarks: "It is well to review the municipal lighting situation as it faces the gas men to-day. In the City of New York there are 44,000 gas mantle lamps and 17,991 incandescent electric lamps; Philadelphia, Pa., has 23,719 gas mantle lamps with 14,616 electric lamps, and 19,105 gasolene lamps. In Boston, Mass., there are over 14,000 gas mantle lamps; in St. Louis, Mo., over 18,000."

In connection with gas street lighting in English cities, it is interesting to note that "in the City of London there are 3 public gas lamps to 1 electric; in Perth, Scotland, 11 gas to 1 electric; in Aberdeen, 20; in Glasgow, 22; in Dundee, 62; in Edinburgh and Leith, 9; in Manchester, 220; in Bradford, 141; and in Liverpool, 122." London has 65,000 gas mantle lamps, and about 4 years ago the entire western section of the city (Westminster) changed over from electricity to gas for the reason that the latter was considered far more efficient and economical. In fact, a saving of $40,000 a year was brought about by the change to gas. There are altogether in Great Britain 771,016 public gas lamps.

* *American Gas Lighting Journal*, September 28th, 1914.

MACHINE TO REGISTER FATIGUE.

ACCORDING to *The Globe* M. J. M. Laby, member of the French Academy of Sciences, in a communication to the Academy has declared that he had studied practical means of scientifically organising the division of labour by determining the degree of fatigue entailed by modern professions that do not demand great muscular exertion. Experiments carried out since 1903 on post-office sorters, printers, linotype operators, and typists, had given absolutely concordant results. The degree of fatigue was determined by the increase in the arterial pressure and the time of the subsequent reaction.

It would certainly be interesting to ascertain whether this instrument could be applied to determine the comparative conditions of fatigue resulting from the use of various methods of illumination.

By some such test we might gradually find out which are the defective conditions of lighting that cause fatigue, and add to the strain of industrial occupation

TOPICAL AND INDUSTRIAL SECTION.

[At the request of many of our readers we are again extending the space devoted to this Section, and are open to receive for publication particulars of interesting installations, new developments in lamps, fixtures, and all kinds of apparatus connected with illumination.

The contents of these pages, in which is included information supplied by the makers, will, it is hoped, serve as a guide to recent commercial developments, and we welcome the receipt of all *bona-fide* information relating thereto.]

EDISWAN ITEMS.

The Edison & Swan United Electric Light Co., Ltd., Ponders End Works, Middlesex, were visited on Wednesday, February 24th, by the members of the Chemical Society, Royal College of Science, South Kensington, Mr. E. W. Swann, their Excursion Secretary, being responsible for the arrangements.

An interesting visit was made to all the lamp manufacturing departments, including carbon and drawn wire sections.

A contract has been accepted by the Booth Steamship Co. for Royal Ediswan metal filament and carbon filament lamps.

A recent **Ediswan** leaflet contains particulars of special fans for steamship and train. Another feature is the special Ediswan Dimmer switch illustrated herewith, with "on," "off" and "half"

positions. It will run a 30-watt lamp down to one candle or a 40-watt lamp down to 5 candles, and will also reduce the speed of standard 12-in. fans to about half speed.

SIEMENS CONTRACTS.

Messrs. Siemens Bros. Dynamo Works, Ltd., announce acceptances of the following contracts for the ensuing twelve months :—

Carbon filament lamps for the London County Council.

Wotan, Wotan half-watt and carbon filament lamps for the Aberdare Council.

Wotan and tantalum lamps for the Middlesbrough Corporation.

Wotan, tantalum and carbon filament lamps for the Croydon Corporation Tramways.

SOME G.E.C. PRACTICAL FITTINGS.

Several practical forms of fittings for workshop and office use have recently been introduced by the **General Electric Co., Ltd.,** One of these is a standard of substantial construction standing about 5 ft. high. The stem is of ash wood on a massive iron base. It carries a transverse wood rod to which is attached a G.E.C. fibre insulated hand lamp. In no part are metal parts in contact with current-carrying wires, and the Home Office requirements are entirely met.

Other novelties of interest include a new form of telescopic bracket capable of up and down motion as well as swing in a vertical plane ; the direction of light from the lamp in reflector at its extremity is also readily adjustable.

NONPAREIL INVERTED INCANDESCENT GAS SUNBURNER.

A leaflet issued by **Messrs. Jas. Milne & Son, Ltd.,** illustrates the Nonpareil Sunburner. An interesting installation of these lamps, at the Leeds Training

College, was referred to in this journal not very long ago.

The light consists of a series of inverted burners mounted under a hood in such a way that besides furnishing a strong downward illumination they have a considerable value for purposes of ventilation. A 28-light of this kind gives as much as 2,100 candles. It is doubtless an advantage that with this number of mantles the fact of any individual mantle deteriorating will not much influence the performance of the unit as a whole.

A considerable number of these units appear to be now installed in London and the provinces.

Typical housing for use with "half-watt" lamps. Similar cases for a great variety of shapes of lamps are available.

HOW TO PLAN LIGHTING INSTALLATIONS.

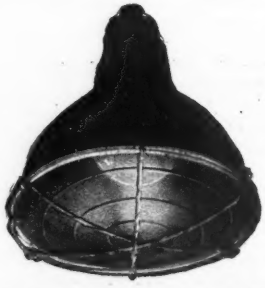
In our last issue (p. 145) we made a preliminary note on .the new B T.H. reflectors for industrial lighting, several of which are illustrated in the adjacent column. The most interesting section of the catalogue information referring to these reflectors is the suggested method of planning installations.

We have described how each reflector has its appropriate combination-symbol which, to the initiated, tells the whole story of its type, and distribution of light and the size of lamp for which it is intended.

In addition to this a couple of key-tables are provided, the first of which divides lighting problems into ten main classes, according to the nature of the work, while the second merely gives the symbols identifying reflectors of varying concentration. By the aid of the chart, shown on the opposite page, the spacing, type of reflector, and size of lamp can be determined. Naturally some judgment and initiative is left to the user of the table; he must, for example, decide correctly the class to which his installation belongs, and he must also make certain decisions as regards spacing.

Altogether the scheme is an ingenious one. There is, however, one addition we should like to see, namely, some indication to the consumer of the resultant illumination with a given arrangement of lamps and reflectors. No doubt, by referring to the polar curves he could work this out from first principles; but it might, perhaps, be made easier for him by another tabulation.

Typical 15° angle Mazdalux reflector; this type is designed both for half-watt and ordinary lamps.



Special local lighting type of Mazdalux reflector with wire cage for factory use. A feature of this unit is the locking arrangement so that neither lamp nor reflector can be removed when sealed.

ADVANCE IN PRICE OF FITTINGS.

The British Thomson-Houston Co., Ltd., advise us that from April 7th onwards there will be a 10 per cent. advance on the price of their fittings.

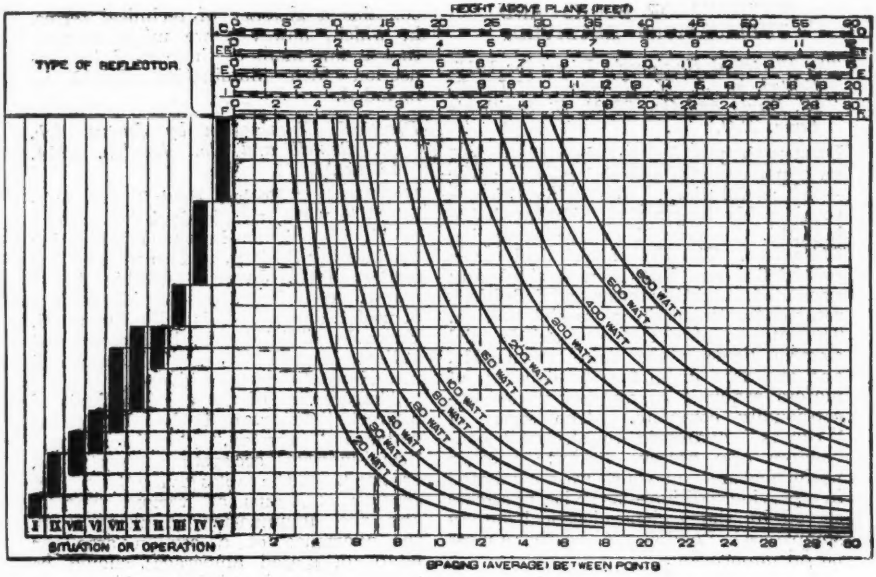


CHART FOR PLANNING LIGHTING INSTALLATIONS.

The application of this chart can only be fully understood by reference to the complete catalogue. The Roman figures at the base of the diagram indicate certain classes of work, tabulated in the catalogue (such as I. stores, II. offices with local lighting, III. tool-making and fine fitting, &c.). Having decided in what category the job falls, we identify the black space on the left and follow horizontal and parallel to this until we meet the vertical line corresponding with the spacing of units preferred (settled mainly by height of ceiling and character of work). The point of intersection with this vertical line gives the size of lamp required. The correct height for the various reflectors (indicated by capital code letters) is set out at the top of the diagram.

GLASSWARE TO GIVE SUNLIGHT COLOUR VALUE WITH INCANDESCENT ELECTRIC LAMPS.

The British Thomson-Houston Co. are putting on the market a complete range of colour-matching pendants and globes to which the name "Trutint" has been applied. We had recently an opportunity of inspecting these globes at Mazda House.

The glass is made in three types according to the class of work for which it is intended, *e.g.*:—

(1) Very accurate matching in colour comparison work, for local use where there is little interference from extraneous light.

(2) The general illumination, giving a light of "noon" sunlight value, suitable for general lighting of paint shops, lithographic plants or art galleries, &c. The efficiency of half-watt units of this class is practically the same as that of the ordinary metal filament lamps in a white opal globe.

(3) General illumination giving a light of "afternoon" sunlight value. This is somewhat more efficient than (2) and gives a somewhat yellower light.

This range of units will, it is hoped, be of considerable value in colour-matching trades and the combination of the blue tint with the diffusing quality of the globes is distinctly novel.

REVIEWS OF BOOKS AND PUBLICATIONS RECEIVED.

The Electrical Engineer's Diary for 1915. *Edited by J. H. Johnson, M.I.E.E. (S. Davis and Co.*, 30-31, *St. Swithin's Lane, E.C.*)

DURING the past few months we have had an opportunity of examining—and using—this useful diary. The 1915 edition is considerably larger than that available in 1914, the printed matter occupying 274 pages. The list of technical terms and definitions has been revised and expanded. Lighting terms and definitions receive treatment in a special section. The notes on interior, street and industrial electric lighting are quite serviceable, and the data given for the capacity of motors required in various trades exceptionally complete. The series of "Don'ts" addressed to electrical contractors also deserve notice. Another useful feature—on which we commented in a previous edition—is the list of streets served by the various electrical supply companies in London. Altogether a most useful publication.

Gas Supply in Principles and Practice. By W. H. Y. Webber. (Whittaker and Co., 2, *White Hart Street, London, E.C.* 1914. 3*s.* 6*d. net.*)

MR. WEBBER is an old hand at this subject, and his book on "Town Gas and its Uses" is probably known to most of our readers. His latest work conveys a considerable amount of up-to-date information. The earlier portion deals with the distribution of gas, gauges, meters, &c. Subsequently we have an example of typical house piping for a dwelling rented at £35—£45 a year, and notes on such questions as the combustion of gas, illuminating *v.* calorific powers, &c. The account of lamps and burners is brought up to date by a reference to the Keith Silica Lamp, and semi-indirect fittings, &c.

The portion of the book that most interests us is that dealing with lighting. We are glad to see that the author lays stress on the avoidance of glare; and, while quoting the general rule of allowing 30-50 candles per 1,000 cub. feet of interior, also mentions the illumination in foot-candles required for various purposes.

There are also notes on the lighting of shops, engineering works, public halls, &c.

The latter part of the book is devoted to a study of the Bunsen flame as a heat-producer, leading up to modern forms of stoves and radiators. The appendix contains a glossary of technical terms, in which, however, we might suggest that a few more of those used in connection with illumination should be included.

Practical Illumination by Justus Eck. (S. Rentell and Co., London. 1914. 1*s. net.*)

MR. ECK'S "Pocket Book" was published in 1914, and is doubtless known to all his friends in the Illuminating Engineering Society, and to many other readers of this Journal. Within the 85 pages it contains a considerable amount of useful, data and it is fully illustrated. Examples of lighting by both direct and indirect systems, using both arc and incandescent lamps, are given.

The account of the chief methods of indirect lighting, and the distinctions between "inverted," "indirect" and "semi-indirect" arc systems in particular, are good, and the tables giving the correct spacing of lamps at various heights, and the illumination resulting from the allowance of a certain area per lamp (of stated amperage), should be useful. Examples of their application to various practical cases are given. The book is concluded by a series of tables enabling cost of carbons at various rates per hour to be calculated.

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INDEX, April, 1915.

		PAGE
Editorial	L. GASTER ..	149
Illuminating Engineering Society— (FOUNDED IN LONDON, 1909.)		
Account of Meeting on March 16th		161
The Rating and Marking of Lamps and the Best Methods of Specifying their Illuminating Value. *Queries on*		162
Discussion—F. W. Willcox—C. H. Wordingham—L. Gaster—C. C. Paterson—J. T. Morris—J. Macintyre—J. Y. Fletcher—T. E. Ritchie—J. G. Clark—M. Foulds—M. le Marechal—Mullard—E. Stroud—R. C. Bussell—F. S. Tilley—J. S. Dow—Prof. Silvanus P. Thompson—A. P. Trotter—F. W. Goodenough—E. Allen—Haydn T. Harrison—G. Keith—J. W. T. Walsh—F. J. Hawkins—H. Staniforth—W. J. A. Butterfield		163
Illuminating Engineering, Short Notes on		186
Practical Rating of Lamps, The	F. W. WILLCOX ..	163
Reviews of Books—		
The Electrical Engineers' Diary for 1915, Edited by J. H. Johnson		
Gas Supply in Principle and Practice, by W. H. Y. Webber		
Practical Illumination, by Justus Eck..		190
Searchlights, A Method of Determining (*concluded*)	A. BLONDEL ..	153
Searchlights, Some Remarks on the More Usual Electrical Systems of Operations	J. F. CROWLEY ..	159
Topical and Industrial Section—		
Ediswan Specialities—G.E.C. Fittings—Siemens Contracts—Nonpareil Sunburner		187
How to Plan Lighting Installations		188
"Trutint" Glassware		189
Insurance Coupon		191
Gaslighting Factory Installation—Use of Gas for Industrial Purposes ..		192

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LOW PRESSURE GAS LIGHTING IN A BODY-BUILDING SHOP.

We are indebted to the Gas, Light and Coke Co. for this illustration of the gas lighting of a body-building shop (Messrs. Van den Plas, Ltd., Westminster). The photograph, taken entirely by the artificial light, is interesting as showing figures at work—always a difficult task for the photographer, and usually impracticable, unless the illumination is very brilliant.

The lighting is arranged to concentrate the illumination on the benches where the work is carried on. It is to be noted that the glass globes of the lamps are protected by wire with a view to avoiding any possible injury from adjacent pieces of wood, &c.

THE USES FOR COAL GAS FOR INDUSTRIAL PURPOSES.

An important paper on the above subject was read by Mr. H. M. Thornton before the Royal Society of Arts on March 19th, Mr. D. Milne Watson being in the chair. As the title implies, the paper dealt with uses of gas other than lighting, but the figures quoted by the lecturer sufficed to show the magnitude of some of these industrial applications.

Some instances of large gas-driven electric-generating sets were mentioned, and a complete account of the heating of large reverberatory furnaces, and the application of gas-heating to hardening, annealing, metal-melting was given. Gas is used for such diverse trades as sugar melting, glass manufacture, cloth industry, hat trade, &c. Of particular interest was the account of the great part being played by gas in the production of munitions of war.

The chairman, Mr. W. E. Price, Mr. F. W. Goodenough, Sir Henry Trueman Wood, Mr. Leon Gaster, and Mr. Campbell M. Hunt joined in the discussion.